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An Investment Decision-Making Process for Investments in Clinical ICT Systems in Public Health Care Organizations

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Abstract

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Keywords: clinical ICT investment, investment decision, contingency theory, contingency variables, public health care

Aspects such as population aging and the ability of governments and municipalities to finance health services have challenged current ways of producing public health care services. Information and Communication Technology (ICT) has the potential to enable a significant transformation in the delivery of health care. Health care organizations lack a framework to assist in investment decisions when investing in clinical ICT systems. This thesis explores the clinical ICT investment decision-making process in a public health care organization. The aim of this study is to systematize the investment decision-making process in order to ensure the financial performance of the investment is in line with the organization’s existing operating environment. This is approached by answering the following two questions: 1) Which contingency factors will, with reasonable accuracy, contribute to the investment decision-making process when selecting a clinical ICT system in public health care? 2) Which contextual variables will, with sufficient accuracy, enhance the performance of clinical ICT system investments in public health care?

The results show that investment decision-making in a public health care organization should begin with an analysis of the alternative technologies and their operational potential (technology variable). Decision-making should particularly emphasize three factors: standards, the integration potential of the system and the strategic fit with the health care organization’s strategy. These should form the basis of the financial analysis of the investment, which is then made using a modified capital budgeting method. The decision-making process should continue with ensuring that other important variables are taken into account. Legislation and the organization’s culture are variables, which should be considered before making the final decision to invest in a clinical ICT system. Since these variables might also affect the technology variable, the financial analysis might need to be re-visited during the decision-making process.

This dissertation identifies the use of the contingency theory in clinical IT investment decisions in a public health care organization from a management accounting perspective. It also analyzes the contingency variables which may contribute to the investment analysis when investing in clinical IT in a public health care organization. Future research will be needed in order to identify the relationship between health care organizations' management accounting systems and investment decision-making process. In addition, the contingency theory should be future tested to provide more insight into how the independent variables interact with each other.

Tiivistelmä

Lamminen, Kirsti Johanna, 2016. "Investointipäätösprosessi investoitaessa kliinisiin tietojärjestelmiin julkisessa terveydenhuollon organisaatiossa". Teollisuustalouden laitos, Tampereen teknillinen yliopisto, Tampere.

Avainsanat: kliinisen tietojärjestelmän investoinnit, investointipäätös, kontingenssiteoria, kontingenssimuuttujat, julkinen terveydenhuolto

Ikääntyvä väestö sekä julkisen sektorin kyky tuottaa ja rahoittaa terveydenhuollon palveluita edellyttävät muutoksia nykyisiin toimintatapoihin. Tieto- ja viestintäteknologia (ICT) mahdollistaa merkittävän muutoksen terveydenhuollon toimintaan ja sen tapaan tuottaa palveluita. Julkisessa terveydenhuollossa on selkeä tarve löytää malli, joka auttaa tekemään investointipäätöksiä investoitaessa kliinisiin tietojärjestelmiin. Tässä työssä tutkitaan kliinisen tietojärjestelmän investointipäätöksen tekoa julkisessa terveydenhuolto-organisaatiossa. Tämän tutkimuksen tavoitteena on systematisoida investointipäätösprosessi, jotta varmistetaan investoinnin kannattavuus sekä investoinnin sopivuus organisaation toimintaympäristöön. Tämä saavutetaan vastaamalla kahteen kysymykseen: 1) mitkä tilannetekijät kohtuullisella tarkkuudella edistävät investointipäätösprosessia valittaessa julkisen terveydenhuolto-organisaation kliinistä tietojärjestelmää? 2) mitkä taustamuuttujat lisäävät riittävällä tarkkuudella julkisen terveydenhuollon kliinisen tietojärjestelmän investointipäätöksen tuloksellisuutta?

Tämä tutkimus osoittaa, että julkisen terveydenhuolto-organisaation investointipäätösprosessi tulee aloittaa analysoimalla vaihtoehtoisia järjestelmiä ja niiden toimintaedellytyksiä (teknologiamuuttuja). Päätöksenteossa tulisi erityisesti ottaa huomioon kolme tekijää: standardit, järjestelmän integroitavuus sekä sopivuus terveydenhuollon ja organisaation strategiaan. Edellä mainitut tekijät ovat perusta käytettäessä erilaisia investointilaskentamenetelmiä. Taloudellisten analyysien jälkeen investointipäätöksentekoprosessia tulisi jatkaa ottamalla huomioon muut merkittävät tilannetekijät. Ennen kaikkea lainsäädäntö sekä organisaation kulttuuri ovat tilannetekijöitä, jotka tulisi ottaa huomioon ennen lopullista kliiniseen tietojärjestelmän investointipäätöstä. Nämä tekijät saattavat vaikuttaa myös teknologisiin valintoihin, joten investointilaskelmia on hyvä tarkastella vielä uudelleen, kun kaikki tilannetekijät on analysoitu.

Tässä väitöskirjassa tarkastellaan kontingenssiteorian käytettävyyttä laskentatoimen näkökulmasta tehtäessä investointipäätöksiä kliinisiin tietojärjestelmiin julkisessa terveydenhuollossa ja analysoidaan investointipäätökseen vaikuttavat kontingenssimuuttujat. Lisää tutkimusta tarvitaan siitä, miten terveydenhuollon organisaation laskentatoimi on kytketty investointipäätöksiin. Lisätutkimusta tarvitaan myös testaamaan sitä, miten riippumattomat kontingenssimuuttujat ovat vuorovaikutuksessa toistensa kanssa.

Preface

This study, conducted in the Department of Industrial Management at Tampere University of Technology under the supervision of Professor Petri Suomala, examines the decision-making process for investments in clinical IT systems in a public health care organization.

Finding a research topic for this dissertation was a story in itself. It all began in the early 2000s when my brother, Heikki Forsvik, MD, was writing his thesis and I co-authored two of the publications. At the time, Heikki encouraged me to continue with my studies. He has been supporting, helping and commenting on my work throughout the journey – always motivating me to find answers. I am especially grateful to Heikki for his everlasting idea generation, and for all his support, particularly in those times when I almost felt like giving up on this project.

In addition, I would like to thank Dr. Ville Voipio also for numerous pieces of good advice, and for being part of our “research team”. Thanks also go to Dr. Mari Tuomaala for reviewing my dissertation, and also for reminding me to keep it short and simple. Without their help, I would not have been able to complete this project while working full-time at the same time.

Professor Arto Ohinmaa and Professor Pekka Rissanen are greatly acknowledged for pre-examining this dissertation.

Also, Professor Keijo Ruohonen and Lasse Lehtonen, MD, LD, the co-authors of research papers are greatly acknowledged. I would like to thank Dr. David Dusseault for good discussions and motivation during the writing of the second last publication. I also would like to thank my niece, Eveliina Forsvik, for helping me to collect the references from various sources.

I am finalizing this dissertation surrounded by great sadness following the death of my father. I had hoped he would be here to see me complete this thesis. My parents, Pentti and Brita, deserve special thanks for their support and for instilling in me the importance of having the right attitude. I wish to thank my husband, Harry, for supporting me to go for my dreams, and our son, Mikko, for bringing joy and importance into Harry’s and my lives.

Contents

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List of publications

This dissertation consists of an overview and the following publications, which are referred to in the text by their Roman numerals.

I Lamminen, J., Forsvik, H., Voipio, V., Ruohonen, K. 2011. “Teleconsultation: changes in technology and costs over a 12-year period”. Journal of Telemedicine and Telecare. Vol.17, No. 8, pp. 412-416.

II Lamminen, H., Lamminen, J., Voipio, V. 2006. “Economic Evaluations in Teleophthalmology”. Teleophthalmology. Springer-Verlag. Chapter 10, pp. 71–76.

III Lamminen, J., Lamminen, H., Voipio, V. 2005. “Integration in telemedicine”. Journal on Information Technology in Healthcare. Vol. 3, No. 4, pp. 236–238.

IV Lamminen, J., Forsvik, H., Voipio, V. 2012. “The EU medical devices legislation in diabetic retinopathy screening”. Acta Ophthalmologica Scandinavica. 90, Suppl. 250:43.

V Lamminen, J., Forsvik, H., Voipio, V., Lehtonen, L. 2015. “Decision making process for clinical IT investments in a public health care organization – contingency approach to support the investment decision process”. Finnish Journal of eHealth and eWelfare. Vol. 7, No. 2–3.

VI Forsvik, H., Voipio, V., Lamminen, J., Hyppönen, H., Doupi, P. 2015. “Literature review of patient record structures from the physician’s perspective”. Methods of Information in Medicine (submitted).

Author's contribution

All the publications included in this dissertation were written in co-operation with other authors. TABLE 1 describes the role of the author in each of the publications.

TABLE 1. The role of the author in each of the publications.

Article	**Role of the author**
I Teleconsultation: changes in technology and costs over a 12-year period (reviewed by two independent reviewers)	- design of the study - collecting measurement data together with the second author - analysis and interpretation of the data with the co-authors - writing the paper and reviewing it with the co-authors
II Economic Evaluations in Teleophthalmology (reviewed and accepted by editor)	- design of the study - analysis and interpretation of the data - writing the paper and reviewing it with the co-authors
III Integration in telemedicine (reviewed and accepted by editor)	- collecting data for the study - writing the paper and reviewing it with the co-authors
IV The EU medical devices legislation in diabetic retinopathy screening	- collecting data for the study - writing the paper and reviewing it with the co-authors
V Decision making process for clinical IT investments in a public health care organization – contingency approach to support the investment decision process (reviewed by two independent reviewers)	- design of the study - collecting measurement data - analysis and interpretation of the data with co-authors - writing the paper and reviewing it with the co-authors
VI Literature review of patient record structures from the physician's perspective (reviewed by two independent reviewers)	- assessing the impacts of data in relation to the evaluation methods and potential improvements in care processes with the co-authors - writing the paper and reviewing it with the co-authors

1 Introduction

1.1 Research gap

Over the past few years in Finland, the rise in health care costs has continued to outpace inflation (National Institute for Health and Welfare, 2014). One of the reasons for rising health care costs is the lack of cost control in hospitals and health centers (e.g. Alho, 2004; Lillrank et al., 2004; Peltokorpi et al., 2004; Peltokorpi et al., 2005; Aaltonen, 2006; Kujala et al., 2006; Aaltonen, 2008; Peltokorpi et al., 2008; Peltokorpi et al., 2009; Peltokorpi, 2011).

Information technology (IT) can be used to develop health care services to make them safer and more patient-centric. IT also helps to develop the processes in order to make health care services more efficient, i.e. cost effective, timely, and equitable. (Suomi et al., 2001; Lamminen et al., 2001a; Kaushal et al., 2005; Scott et al., 2005; Chaudhry et al., 2006; Shekelle et al., 2006; Goldzweig et al., 2009; Shekelle and Goldzweig, 2009). Chaudhry et al. (2006) studied 257 articles, most of which addressed decision support systems or electronic health records. According to Chaudhry et al., the systems taken into use can increase adherence to guideline-based care. According to the study (Chaudhry et al., 2006), such systems enhanced surveillance and monitoring, and decreased medication errors. In the different organizations, the major efficiency benefit shown was decreased utilization of care (Protti and Guerriere, 2012). Shekelle et al. (2006) included 256 studies in their analysis according to which Health Information Technology (HIT) has the potential to enable a significant transformation in the delivery of health care, making it safer, more effective, and more efficient. Some health care organizations have already realized major gains through the implementation of multifunctional, interoperable HIT systems. Shekelle and Goldzweig (2009) identified 4,683 titles in their library search and selected 183 studies for detailed review. Their analyses were based on statistical modeling techniques and indicated that HIT has the potential to deliver health care services more safely, more effectively, and more efficiently. Scott et al. (2005) showed in their study that electronic medical record (EMR) systems have great potential to improve the quality of health services.

Applications of communication and information technologies in medicine are commonly referred to as telemedicine and medical informatics. Telemedicine consists of all forms of electronic communication between patients and providers (Institute of Medicine, 1996). Telemedicine is considered more as a process, rather than a technology, since it connects patients and health care

professionals in a chain of care (Wootton, 1996). Medical informatics can be viewed as the intersection of information science, computer science and health care. Medical informatics includes health care delivery processes that are supported by computers helping in analyzing electronic data (Christensen and Remler, 2007). In this thesis, the clinical ICT system is defined as an ICT system which consists not only of the system used in a reasonably simple medical diagnosis, but also other types of systems which are needed in a health care process.

The broader variety of choices available for technological investment and the increase in Information and Communication Technology (ICT) spending have led public health care organizations to critically evaluate potential ICT investments and the value they deliver for the organizations (Sims, 1999; Devaraj and Kohli, 2000; Forsström et al., 2012). Investing in ICT systems is always a multi-stage, interactive decision-making process (Stryker, 1965; Argyris, 1966; Drucker, 1966; Etzioni, 1989; March, 1994; Hammond et al., 1999; Hayashi, 2001) in which different capital budgeting methods and techniques are used to evaluate, select and allocate resources to investment projects (Haka et al., 1985; Haka, 1987; Sangster, 1993; Segelod, 1998; Murto and Keppo, 2002; Chatterjee et al., 2003; Miller and Waller, 2003; McGrath et al., 2004; Verbeeten, 2006).

In health care, there is a large number of studies examining the effectiveness related to individual treatments and an organization's health care processes, but not top-level decision-making processes in general. There is no single consistent ICT investment decision-making model for public health care organizations (Schiederjans et al., 2010). Health care organizations lack a clear decision-making framework to assist in the structuring of ICT investment decisions (Southard et al., 2012). At the same time, there is also a lack of data and research related to overall ICT systems in public health care (Publication VI).

Use of the contingency theory in clinical ICT investment decision-making has not been studied, either. The theory could provide a relevant set of variables which would help public health care organizations in their investment decision-making processes. Therefore, this dissertation provides information about clinical ICT investments and how a decision-making model based on the contingency theory can be used to improve investment decisions and ensure that the decisions made achieve their objectives.

1.2 Overview of the dissertation

This dissertation comprises four articles, one book chapter and one conference paper, each using different research methods. The results of this dissertation are based on the findings of the research publications. The overview of the summary consists of six chapters organized as follows:

1. Introduction including an overview of the dissertation and research objectives and questions, the methodology used as well as the limitations of the research and research structure
2. Description of the Finnish public health care system and how it has been financed as well as the development of ICT in the health care sector
3. ICT investments and their assessment in a health care organization
4. Contingency theory review
5. Results consisting of the key findings of the research and discussion
6. Discussion

The first chapter gives an introduction to the research, the research gap and the research questions. The research questions have been formulated to consider the contingency theory in clinical ICT system investment decision-making in a public health care organization. In addition, the first chapter discusses the methodology employed and the limitations of the research. The second chapter introduces legislation governing the Finnish public health care system, the system's overall structure and the development of financial accounting systems in order to identify how decision-making and decision-making powers are organized in public health care systems. The chapter also gives an overview of the financing of the Finnish health care system.

The third chapter introduces the division of costs and the cost analysis in a public health care organization. The chapter continues with the investment assessment and criteria for the investment decision, providing a preview of the criteria for investing in information technology in a health care organization. Investment decisions are mainly driven by cost factors, whereas cost analyses form the bases for the investment analyses.

The fourth chapter introduces the contingency theory. This chapter aims at finding a practical decision-making process capable of taking the different financial and non-financial factors into account.

The fifth chapter presents the variables which will improve the investment decision-making process. It also covers the contextual variables that impact the financial performance of clinical ICT investment in public health care.

In the sixth chapter, discussion is based on the contribution of the research and future research ideas. The last chapter also consists of the research assessment with a discussion of the relevance, validity and reliability of the research.

1.3 Research objective and questions

The objective of this dissertation is to systematize the investment decision-making process to ensure the financial performance and investment are in line with the organization's existing operating environment when investing in clinical ICT systems in a public health care organization.

The financial analysis for investment decisions should also consider other variables beyond costs (Brown, 2005; Sintonen, 2007; Yates, 2009) and be supplemented with the relevant factors. The relevant factors contributing to the cost analysis of a clinical ICT system (including telemedicine) investment are factors such as the quality of care (Rosenstein, 1999), patient experience, including the time savings for the patient, the organization's internal process improvements (Sims, 1999; Lamminen et al., 2006; Remenyi et al., 2007), and the organization learnings (Lamminen et al., 2006).

Compared to many other industries, the health care industry has been relatively slow to adopt ICT (Kaplan, 1997; Shortliffe, 2005; Sistrom, 2005; Christensen and Remler, 2007; Christensen and Remler, 2009). Today, health care organizations are constantly seeking innovative use of ICT, such as telemedicine, mobile health and e-service in order to improve their processes (Sethi and King, 1994; Wootton, 2009). Specific issues such as the costs associated with hardware and software, availability of broadband and mobile networks, development of user interfaces, and ongoing maintenance costs are evident in the ICT investment decision-making process (Wootton, 2009). However, in the investment decision, it is more difficult to evaluate the financial value related to the ongoing development of technology, the present level of standardization and interconnectivity (Goroll et al., 2009; Jha et al., 2009; Lorenzi et al., 2009). In a public health care organization, the administrative management prepares investment proposals while politicians make the final decision (Kurunmäki, 1999).

Therefore, the first research question can be formulated as follows:

***Research question** 1: Which contingency factors will, with reasonable accuracy, contribute to the investment decision-making process when selecting a clinical ICT system in public health care?*

According to the contingency theory, the efficiency of decision-making depends on a number of aspects, such as the amount of relevant information and decision quality and acceptance, within a specific situation (Vroom and Yetton, 1973). The contingency theory connotes a conditional association of two or more independent variables with a dependent outcome (Drazin and Van de Ven, 1985). The fit is understood as a positive impact on performance, and the research task is then to explain variations in performance in terms of interaction effects between context and structure (Gerdin and Greve, 2004). However, if the factors that affect decision-making when investing in clinical ICT systems are linked to the purposes of use, the appropriate design of the decision-making model may not be understood without reference to their actual usage.

In public health care, the evaluation process concerning different ICT systems has to be transparent. The factors affecting the final decision already need to be identified at the beginning of the process. The overall performance of the investment decision is dependent on contextual variables, variables which have financial value and which can be part of the cost analysis, as well as variables whose exact financial value is hard to assess.

The contingency theory explains the circumstances in which a relevant set of variables being considered in a decision-making process coincides with the actual parameters relevant to the process. A contingency-based investment decision approach would give a more balanced view of the various parameters employed and help ensure the performance of the clinical ICT investment decision.

The contingency theory approach is a viable tool since the selection of a clinical ICT system in a public health care organization is influenced by internal and external constraints. The theory seeks to understand which external factors, such as preferences of the surrounding community (Barry and Chaiken, 2003), in particular have an impact on the organization's operations or which internal factors must be taken into account for an optimal investment. The effectiveness of a decision depends on a balance of how important the decision is from an external variables point of view, and how well the new clinical ICT system is compatible with the organization’s internal processes and strategy. Changing the nature of one factor will alter the relationship with the other variable. When

analyzing investments in a public health care context, it is also important to consider the special features of a non-profit organization (Leväsvirta, 1999, p. 92).

Therefore, the second research question can be formulated as follows:

Research question 2: *Which contextual variables will, with sufficient accuracy, enhance the performance of clinical ICT system investments in public health care?*

Cost savings are not always the main reason for investing in clinical ICT. An improvement in service quality also has a significant role in the investment decision. Since the investment should either produce cost savings or improve service quality, both aspects need to be considered in the financial calculations. While investment theories mainly emphasize quantitative appraisals, there is no self-evident methodology for a contextual analysis of ICT systems beyond financial considerations (Pirttivaara, 2010). Health care organizations should evaluate the suitability of their ICT investments (Remenyi et al., 2007) in terms of indirect costs and benefits (Sorenson et al., 2008).

In a public health care organization, all investment decisions have to be based on factors which are openly communicated in advance to all stakeholders. The entire decision-making process also needs to be open and transparent. However, factors such as client experience and organizational learning are usually very difficult to express in financial terms, and therefore their inclusion adds considerable uncertainty also regarding investment calculations.

Together, these research questions address the problem of how to design an investment decision-making model that is able to take the different financial and non-financial factors into account. The lack of a structured method to conceptualize the complex environment seems to lead to a situation where decisions are often based on intuition and recommendation by trusted parties. While this more intuitive line of work may produce good results, it has its obvious risks. This problem becomes more acute as today's ICT systems are becoming complex and intertwined, and an increasing amount of specialist knowledge is needed to understand the essentials.

The contingency approach is not commonly applied to the study of decision-making, but it was chosen to be evaluated in this study due to its main proposition that the structure and process of an organization must fit its context in order to be effective (Drazin and Van de Ven, 1985). The theory acknowledges the complexity and uncertainties behind decisions.

1.4 Research design and methods

1.4.1 Overall research approach

The philosophy of science includes an understanding of the research background, a view of reality (ontology) and knowledge of reality (epistemology) (Tuomi and Sarajärvi, 2002).

Typical research extracts within business economics can be linked either to positivism or to hermeneutics (Olkkonen, 1994). The interpretivism approach adopts the broad goal of illuminating a set of social meanings that reflect cultural beliefs and values, while the positivist approach seeks causal laws to explain objectively-viewed phenomena (Roth and Mehta, 2002). TABLE 2 illustrates the most important differences between the positivism and interpretivism (hermeneutics) approaches by Roth and Mehta (2002).

TABLE 2. Summary of the positivist and interpretivism approaches (Roth and Mehta, 2002, p.136).

Positivism	**Interpretivism (hermeneutics)**
Causation – Seeks to understand the causal explanation for a phenomenon or event	Interpretation – Seeks to understand how people interpret a phenomenon or event
Objective reality – Presumes the "existence of facts"	Subjective reality – Recognizes the "construction of facts"; facts are seen as interpreted and subjective
Generality – Analysis seeks a "law" that extends beyond specific instances studied	Specificity – Analysis is context specific and based only on the subjective understanding of individuals within a specific context
Replicability – Analysis can be tested and verified empirically against other cases	Self-validation – Analysis can only be self-validating, through the consistency and coherence of "thick descriptions"

Positivistic research typically concentrates on description and explanation, whereas hermeneutic research deals with understanding and interpretations (Gummesson, 2000; Bryman and Bell, 2007, pp.16–18).

The philosophical basis of this dissertation is closer to hermeneutics than positivism. Also descriptive research aims to create concepts and describe processes, whereas normative research aims to identify results that may be used as instructions for developing operations or designing new constructions (Kasanen et al., 1993; Olkkonen, 1994). The viewpoint in this dissertation is that research should lead to change in the decision-making process, and therefore that change should

be incorporated into the research process itself (Easterby-Smith et al., 1991). Since the study aims to pursue an in-depth understanding of a particular phenomenon and to create a theoretical construction from case-based empirical evidence, a case study appeared to be the most suitable research approach (Eisenhardt, 1989; Hamel et al., 1993; Yin, 1993; Keating, 1995; Stake, 1995).

Qualitative research is typically related to hermeneutics, whereas quantitative research often represents positivistic thinking (Gummesson, 2000, p.178). Qualitative research strives for a comprehensive picture of the research object with in-depth examination, whereas quantitative research includes an examination of numerical data with an objectivist conception of social reality (Gummesson, 2000; Bryman and Bell, 2007). The researcher does not seek any causal explanation or law-like relationships in the question of interest. The researcher is independent and makes the observations as an outsider, focusing on meanings instead of facts (Easterby-Smith et al., 1991; Coughlan and Goghlan, 2002). The context is specific and the analyses are based on the researcher's understanding of what is happening. The researcher uses multiple methods to establish different views of phenomena, and many of the results are based on the researcher's normative arguments.

The following approaches are often used in industrial management research (Neilimo and Näsi, 1980; Kauranen et al., 1992; Kasanen et al., 1993; Olkkonen, 1994):

1. **Conceptual analysis** aims to develop new concepts and conceptual systems. The utility of conceptual analysis for archival science is assessed by means of an exploratory evaluation in which the concept of evidence is analyzed.
2. **The nomothetic approach** aims to discover empirically valid laws. The nomothetic model attempts to find independent variables that account for the variations in a given phenomenon. The empirical part of the decision-making methodology is mainly to provide an application example.
3. **The decision-making methodology approach** regards decision-making as the mental processes (cognitive process) resulting in the selection of a course of action among several alternative scenarios.
4. **The action-analytical approach** aims at understanding the subject of the study and at developing new concepts on this basis. The main benefits of this approach are that the quantities are directly measurable, the assumptions are easily verified, and the results are not derived using advanced queuing theory. This makes the results easier to understand and apply. Studies which use operational analysis approaches are often based on long periods of observation.

Since the phenomenon of interest in this dissertation is the actual ICT investment decision-making and the aim is to understand how different contingency variables interpret the decision-making and the usage of investment criteria, the action-analytical approach was used. There is a need to understand how different contingency variables affect decision-making when investing in clinical ICT systems in health care. According to the contingency approach, the effectiveness of decision-making in an organization depends upon a number of aspects, such as the importance of the decision, the amount of relevant information available and the acceptance of or disagreement with the decision by others (Vroom and Yetton, 1973). Technology, including various ICT systems (i.e. telemedicine), is already used in the health care sector, and there are several studies confirming that the use of IT will result in process efficiency, i.e. deliver cost savings. The purpose is also to interpret these observations to provide some explanation for the prevailing practices.

This dissertation examines one large health care organization and one small health care center in Finland. These particular cases were chosen mainly because of the possibilities to analyze the results of a clinical ICT infrastructure which is already up and running. A practical reason for choosing these particular implementations instead of many others was because the researcher is familiar with the cases, and the representatives were willing to participate in the studies. However, the main logic in the case selection was replication in order to achieve better potential for generalization. It was estimated that experience from these cases could be generalized to not only organizations of the same size, but also potentially to other public health care organizations with similar needs to improve their efficiency by investing in clinical ICT systems.

Case study was used as the research approach in this dissertation, and different research methods were used in the publications. Yin (Yin, 1981) defined case study as a research strategy in which qualitative methodology, qualitative data and participants' observations are commonly associated (Voss et al., 2002; Eisenhardt and Graebner, 2007). Case study starts with a research question (Voss et al., 2002) which typically answers 'how' and 'why' questions.

Case study is also often used to test theories (Yin, 1993; Keating, 1995; Yin, 2009). While most of the cases are in a real-life context, the researcher has little or no possibility to control the events (Yin, 1993; Yin, 2009). A case study can also sometimes be more meaningful and attractive to practicing managers than preoccupation with often abstract variables, which characterize much of quantitative research (Yin, 2009).

Case study has been criticized as having only limited possibilities to be generalized (Ragin and Becker, 1992; Hamel et al., 1993; Yin, 1993; Stake, 1995; Gillham, 2000; Yin, 2009). One of the weakest elements in case research is the failure to explicate the theoretical contribution case study makes to literature (Ferreira and Merchant, 1992).

The large variation between the publications makes the selection process between positivistic research and hermeneutic research challenging. Hermeneutic research was selected and the case study in this dissertation draws on as much (numeric) objective data (such as costs, and number of patient visits) as possible in its analyses in order to emphasize the subjective reality.

1.4.2 The contingency theory as the theoretical perspective

According to the contingency theory, there is no one best way of organizing or leading a company. Instead, the optimal way is contingent upon the internal and external situation at hand (e.g. Burns and Stalker, 1961; Fiedler, 1964; Woodward, 1965; Lawrence and Lorsch, 1967; Donaldson, 2001). Central to the contingency approach is an examination of the relationships between strategic priorities, organizational configurations and management accounting systems in the notion of contingent fit. According to this approach, performance is not directly affected by the type of strategy or by the organizational configuration (Jermias and Gani, 2004). The theory seeks to understand which external factors in particular impact the organization's operations or which internal factors must be taken into account for an optimal investment. However, the contingency theory has been adopted by management accounting researchers in order to explain the functionalities of management accounting systems for organizations (Waterhouse and Tiessen, 1978; Otley and Berry, 1980; Fisher, 1998; Chenhall, 2003; Kajuter and Kulmala, 2005). The theory can also be applied in complex investment decision-making. While there is no universally appropriate management accounting system that will apply equally to all organizations in all circumstances (Emmanuel et al., 1990; Haldma and Lääts, 2002), the importance of different variables also varies in organizations' investment decision-making. The effectiveness of the design of an accounting system that supports investment decision-making depends on the system's ability to adapt to changes in external and internal variables (Haldma and Lääts, 2002; Kajuter and Kulmala, 2005).

Researchers have used the contingency approach to attempt to explain the efficiency of accounting and management control systems by examining designs that suit the nature of the environment, size, structure, technology, strategy, national culture and international competition (see Chapman, 1997; Reid and Smith, 2000; Chenhall, 2003; Jokipii, 2006 for a review). When reviewing accounting

literature and publications based on use of the contingency theory, the most frequently repeated situational factors are (Burns and Stalker, 1961; Lawrence and Lorsch, 1967; Otley, 1980; Drazin and Van de Ven, 1985; Donaldson, 2001) the external environment (Khandwalla, 1977; Merchant, 1990; Chapman, 1997; Hartmann, 2000), technology (Khandwalla, 1972; Merchant, 1984; Dunk, 1992), strategy (Miles and Snow, 1978; Gupta and Govindarajan, 1984; Chenhall and Morris, 1986; Simons, 1987) and organization size (Khandwalla, 1972; Bruns and Waterhouse, 1975; Merchant, 1981). The effectiveness of a management accounting system (planning and controlling) will depend on the extent to which the system's characteristics meet the requirements of the various contingency variables faced by the organization.

Contingency variable can have several factors, which define and explain the variable. In this dissertation, those factors are called contingency factors. Contingency factors, which have economically measurable values, are called contextual variable.

1.4.3 Methods used in the publications

The empirical material for Publication I, "Teleconsultation: changes in technology and costs over a 12-year period", was collected in 1997 and is based on the teleconsultations performed between a health center in a small Finnish town and a university hospital located 55 km away. The empirical material was collected for the article published in 2001 and is presented in that article (Lamminen et al., 2001a). According to that article, telemedicine consultations were carried out in respect of a total of 110 patients in ophthalmology, and 115 patients in dermatology. Publication I sought to re-design the previous technology environment to meet the present potential system set up to provide similar teleconsultation. The same empirical data which were collected for the earlier study (Lamminen et al., 2001a) were used with updated cost information.

Publication II, "Economic Evaluations in Teleophthalmology (2006)", is based on the findings and empirical data in the authors' earlier publication (Lamminen et al., 2000; Lamminen et al, 2001b), which relates to a study in Ikaalinen health center. Publication II is based on consultations in which a videoconferencing unit, modified document camera and a dermatoscope for close-up pictures were used. The specialist at Tampere University Hospital had a videoconferencing unit from which snapshot pictures of selected areas of skin could be captured. Consultations were scheduled to be held every other week at a fixed time. Patient case history, laboratory results, current status and the clinical problem were sent to the specialist before the consultation. All procedures during the consultation were guided by the dermatologist. The diagnoses were checked 16 months later.

Immediately after the consultation, a questionnaire was given to the patient, specialist and GP. The answers to the questions were either 'yes' or 'no', or were on the five-point Likert scale. The study lasted eight months and a total of 25 patients participated in teledermatology consultation.

Publication III, "Integration in telemedicine", was conducted as a literature review related to telemedicine and videoconferencing. The authors also gained knowledge during the implementation of the systems when writing earlier articles in 2000 and 2001. The ICT used in the previous studies was the most relevant technology at that time. The setup was selected, with the help of IT consultants as well as communications experts (from a telecommunications company), to be as user friendly as possible for both the specialist and the GP. Data were also collected from literature reviews, by reviews exchanging ideas and by interviewing other researchers working with clinical IT systems.

The literature reviews and interviews with the medical specialists and communication experts were used for the congress paper, Publication IV, "The EU medical devices legislation in diabetic retinopathy screening. XXXX Nordic Congress of Ophthalmology", in 2012. Data collection for the paper was done partly by using regulation literature as the source material and by the exchange of personal communications within the industry.

The empirical material for Publication V, "Decision making process for clinical IT investments in a public health care organization – contingency approach to support the investment decision process", was carried out in spring 2013. The research was conducted by reviewing material and interviewing the personnel involved in the project regarding HUSLAB's clinical IT investment decision process. The material related to the investment decision included the organization's strategy papers, IT strategy, materials related to the vendor selection process, investment analysis and selection criteria, together with the results of the selection process, standard agreement templates for acquiring the system, maintenance and support service, and the material related to the purchase submitted to the Board of Directors, as well as the minutes of the Board of Directors of the Hospital District of Helsinki and Uusimaa (HUS). The material tracks the case from the strategy paper written in 2005 until the final IT decision made by the Board of Directors in May 2008. The financial data provided for the analysis were actual data from the organization's accounting system. It was considered that six interviews (see Appendix 1) were required in order to gain a comprehensive understanding. Each interview lasted approximately two hours. The interviewees were the managing director of HUSLAB and the IT system's project manager. The interviews were documented and sometimes complemented by sending follow-up questions by email.

The data in Publication VI is based on a literature review which consisted of original articles found by using a systematic review protocol developed in the framework of a wider literature review on structuring electronic patient health record (EHR) data. The purpose of Publication VI was to present a literature review of the methods of structuring patient records and assessing the impact of data structures in clinical use. The original literature search consisted of a total of 744 identified articles from different databases. The selected articles underwent several exclusion rounds.

In the primary selection, only articles in Finnish, Swedish or English and studies which were carried out in countries other than low or lower middle income countries were selected. In the second phase, the articles were divided into four different categories (earlier reviews, nursing-related articles, articles concerning secondary use of the data and the physicians' viewpoint) using three criteria: population, intervention and outcome. The systematic review procedure and analysis of the reviews has been published earlier (Hyppönen et al., 2014), as has been the analysis from the nursing viewpoint (Saranto et al., 2014).

The resulting articles were assessed to select those with the physicians' viewpoint. A total of 77 articles underwent a second round of selection by two independent reviewers based on three criteria (population, intervention, and sufficient evaluation). The agreement between reviewers was reached by negotiation. The remaining articles (n = 40) were classified both quantitatively and qualitatively with parameters based on the analysis framework developed in the first phase of the study. The final exclusion round was performed on the articles based on non-compliance with the three criteria: population, intervention (EHR and data structures) and outcome (sufficiently clear description of the evaluation of structured data). In this phase, both reviewers together re-evaluated articles that they disagreed on.

In practice, exclusion was performed as a three-step criterion-by-criterion evaluation for each article. If an article failed to meet a criterion, it was excluded without evaluating it against the remaining criteria. Each exclusion was thus documented by the first criterion lacking, although some articles could have failed to meet more than one criterion.

After this exclusion round, only the articles which met all the criteria remained. The articles excluded due to the wrong population typically described a setup where physicians and members of other professional groups were studied together in a non-separable way. Thus, it was not possible to reliably extract the physicians' point of view from the evaluation results. Quantitative measurements or rigorous statistical analysis were not required for inclusion in this review since these criteria would

have made the remaining material scant and possibly excluded some otherwise highly relevant articles. TABLE 3 shows the publications and how they relate to the research questions. The research methods and data collection methods used in each publication are described.

TABLE 3. Summary of the appended publications, research questions, methods and data collection.

Publication	Link to the research questions	Methods and data collection
Article I Teleconsultation: changes in technology and costs over a 12-year period	**1 and 2:** Investing in clinical IT systems will bring cost savings. Technology is the key variable in investment decision-making, although technology is changing rapidly.	- case demonstration in which the empirical data were collected for the earlier study and were used with updated cost information
Article II Economic Evaluations in Teleophthalmology	**2**: IT enables a health care organization to become more patient-centric and improve efficiency. Variables beyond the costs need to be taken into account when making the investment decision to invest in clinical IT.	- case study in which the data are based on the findings and empirical data in the authors' earlier publications
Article III Integration in telemedicine	**1**: Integration and standards are the most important factors to be considered when selecting the IT system.	- literature review (literature selected through practical experience)
Conference paper IV The EU medical devices legislation in diabetic retinopathy screening. XXXX Nordic Congress of Ophthalmology	**1:** Clinical IT systems need more standards and in the investment decision standards have a key role when selecting the IT system.	- literature review - interview study
Article V Decision-making process for clinical IT investments in a public health care organization – contingency approach to support the investment-decision process	**1 and 2:** Technology, legislation and the organization's culture are the most important variables affecting the quality of decision-making in the clinical IT investment decision. The financial analysis should consider integration, standards and the overall strategy when analyzing the required investment itself.	- case study - interview study
Article VI Literature review of patient record structures from the physician's perspective	**2**: The scattered nature of research in the field of EHR systems hinders the generalizability of the findings. The contingent nature of EHR systems makes it challenging to design a national multi-disciplinary EHR archiving system.	- literature review in which a total of 77 selected articles from different databases were used

1.5 Research limitations

This study examines the investment decision related to clinical ICT investments from the point of view of top administrative management and physicians. Although services have been outsourced in many Finnish public health care organizations, specific features of outsourcing are not in the management interest of this study. The investment decision-making process problem is seen from the contingency theory perspective with an emphasis on micro-level examination.

This study examines the technology from the clinical ICT system's point of view and does not include applications such as patient registry. The limitations of this study include the use of only mid-sized health care organizations, which are defined as those serving a range between a town with approximately 10,000 inhabitants and the Hospital District of Helsinki and Uusimaa (HUS), a joint authority formed by 24 municipalities.

This dissertation focuses on investment theories analyzing from the contingency theory perspective, which assigns the most relevant variables in the investment decision-making process in the health care sector. This dissertation does not set absolute values for each of the factors analyzed and focuses only on decision-making related to clinical ICT systems in public health care organizations. The decision-making process itself – including governance or decision-makers – was not studied in greater detail.

Regarding the internal contingency variables point of view, this study analyzed the ICT, organization culture, and strategy. Regarding the external variables point of view, legislation was analyzed. The contingency variables analyzed were seen to impact investment decisions. The nature of the Finnish public health care sector (non-profit organization) affected the selection of external variables. External factors such as competition and customer preferences were not analyzed.

The empirical context of this study is based on real-life cases in two public health care organizations, as well as on literature reviews. The use of real-life cases lends credibility to the results obtained from the study, but obviously the wider applicability of the results hinges on whether the cases studied were representative or not. The cases seem to have no specific features which would set them apart from other similar investment cases. Also, the internal and organization type related factors encountered in the cases seem to be generic across different public health care organizations. However, since the environment was similar in the cases (Finnish public health care

organizations of a certain size), caution is required when applying the results to other countries or to significantly smaller or larger organizations.

Investment decision and investment calculation research are very multidisciplinary. However, the investment decision-making process refers quite often explicitly to investment calculations, even though there are many other factors affecting the investment decision. This dissertation defines the investment assessment for the required investment itself, but the values for the factors are not presented as they are beyond the scope of this project.

Also, it would be unreasonable to expect the results of this decision-making process to be absolute results. Instead, they are more of a starting point for future research. It is obvious that more research is needed to further develop and conceptualize the ICT system investment decision-making process for public health care organizations.

2 Financing of the public health care system in Finland and development of ICT in the health care sector

2.1 Development of financial structures

Every municipality, either independently or as a joint authority with other municipalities, organizes primary health care and specialized hospital care for its inhabitants. The Primary Health Care Act of 1972 (*kansanterveyslaki*, 66/1972 as amended) stated that all citizens were to be offered universal and affordable health care. Under that Act, in force until the end of 1992, health care delivery was developed under a five-year national planning system. In the 1980s, the Finnish health care system was considered an 'internationally acknowledged prototype for a publicly planned delivery system'. In 1982, Finland was designated by the World Health Organization as a model country for the achievement of the 'Health For All' goals (Saltman and Otter, 1992).

During the 1980s, government officials had financial power over the health care system. This meant that they had not only the right to refuse support for investment, but also to cut off state support for previously agreed expenditure (Linna, 1999). While municipalities were funding a substantial share of health expenditure, it became very clear that they began to resist systems over which they had no effective control (Saltman, 1988; Linnakko and Back, 1994; Kurunmäki, 1999; Linna, 1999).

In 1989, the Act on Specialized Medical Care (*erikoissairaanhoitolaki* 1062/1989, as amended), introduced the concept of hospital districts formed by joint municipal authorities. These districts assumed some of the tasks (i.e. resource allocation) that used to belong to state provincial offices (Kurunmäki, 1999; Linna, 1999). In 1992, the Act on Planning and Government Grants for Social Welfare and Health Care (*laki sosiaali- ja terveydenhuollon suunnittelusta ja valtionavustuksesta* 733/1992, as amended) under which planning control was delegated to the municipal level and government grants were also allocated to municipalities. Also the bases for the calculation of grants were changed. Under the new reformed system, government grants for the running costs of social and health services were calculated according to demographic criteria, whereas earlier the amount of grant was calculated on the basis of the actual cost of operating the existing health care institution. The demographic criteria included population age structure, morbidity, population density, land area, and the financial capacity of the municipality. At the same time, municipalities were given the right to enter into health service contracts in which the purchaser and the provider are free to negotiate any type of contract for reimbursement (Linnakko and Back, 1994; Kurunmäki, 1999; Linna, 1999).

By increasing the financial power, and giving the freedom to purchase services freely (from any provider, public or private), the government delegated responsibility for financial control and the development of health care services to the municipalities (Häkkinen, 1995, pp.128–129). After this, a legislative amendment dramatically changed reimbursements to hospitals. After the reform, the old system that had allocated resources to hospitals on the basis of their average in-patient day and outpatient visit costs was replaced by detailed pricing of health care services (Ministry of Social Affairs and Health, 1992). Although the Ministry of Social Affairs and Health (1991, 1992) had recommended that hospital invoicing should be based on service packages, hospital districts defined and calculated prices for their services without nationally binding guidelines (Häkkinen, 1995; Linna, 1999). At the same time, the need for more explicit and reliable cost accounting was raised. It was believed that accounting numbers would reveal operational inefficiencies within the health care system, the idea being that resources could be used more effectively by giving a monetary value to health care service outputs and comparing them with the resources consumed. (Meklin and Näsi, 1994; Kurunmäki, 1999; Linna, 1999).

The Local Government Act of 1995 (*kuntalaki* 365/1995, which entered into force on July 1, 1996) strengthened the increased autonomy of the municipalities in their duty to provide a variety of services. It was also considered that financial reporting provided insufficient information for management purposes. The bookkeeping and financial statements of the municipalities would come within the scope of the Accounting Act (*kirjanpitolaki* 1336/1997) since the beginning of 1997

(Mayston, 1993; Kurunmäki, 1999).The main task of the accounting system was to help the financial department of a hospital to control the spending on resources during the budget period (Kurunmäki, 1999; Linna, 1999). The operating costs incurred for an average in-patient day and an average out-patient visit were calculated in each of the health service institutions on a one-year basis. During the early 1990s, efforts to increase the cost-awareness of health professionals and to improve the ability of funders to control the services provided resulted in hospitals modifying their official accounting practice, i.e. making changes in budgeting, cost accounting, and financial reporting (Kurunmäki, 1999).

The Health Care Act (*terveydenhuoltolaki* 1326/2010) entering into force on May 1, 2011 gave customers greater freedom of choice. The Act allows customers not only to freely choose the place of treatment but, where possible, also the healthcare professionals who will take care of them.

When giving the freedom to purchase services from any provider, public or private, the government delegated the responsibility for health service development and financial control to the municipalities. At that time, the government was no longer directing municipalities' ICT investments. A public health care organization changes its information system at long intervals, which is why buyers are not necessarily experienced in ICT procurement. This also affects the contract negotiations, in which the client is rarely able to keep control over the issues of future relevance (Forsström et al., 2012).

Municipalities have autonomy regarding the organization of their local health care system. In a public health care organization, the administrative management prepares investment proposals and politicians make the final investment decision. Management accounting practices in public health care started to develop in the early 1990s. This was important because, according to Kurunmäki (1999), the main task of the accounting system earlier had been to help the finance department control and balance the organization's spending during a budgetary period.

2.2 Development of ICT in the health care sector

2.2.1 Development of ICT

There is a lack of studies related to the large-scale implementation of clinical ICT systems. Also most of the studies (articles and case studies in conference papers) related to the implementation of health information systems are about successful implementations, with just a handful of writings pointing out the significant number of health information system failures (Porta, 2004; Heeks, 2006). Health

care is increasingly dependent on ICT, but the accumulation of data has outpaced the capacity to use it to improve operating efficiency, clinical quality and financial effectiveness (Ferranti et al., 2010).

The development of clinical ICT systems is not only dependent on the development of technology infrastructure, but also on the development of software. Computerized electronic medical records enable providers to improve data accessibility and accuracy, provide legible and complete information, reduce data entry repetition, offer online reporting capabilities, reduce duplication, and improve productivity while reducing errors and cutting labor and office supply costs (Rosenstein, 1999; Ferranti et al., 2010; Munyisia et al., 2011). There is still a quite limited number of large-scale electronic health records (EHR) systems in use. Subsequently, the number of studies related to these systems is also rather low (Forsvik and Voipio, 2014).

When providing an adequate level of data structure, the technical standards to forward data between different systems, practical network-based co-operation is called for. Both the acquisition and dissemination of knowledge have become more effective – the internet in particular provides a fast, efficient way to distribute new information (Domingo, 2010). Social networks have grown and provide an active platform for sharing ideas, discussing symptoms and debating treatment options (Domingo, 2010).

Patient privacy and data security are critical factors to be secured (information security requirements). Managers in the organizations handling this data need to ensure that policies, practices and procedures for processing health information are taken into account. Implementation of ICT systems in health care has been limited by a lack of generalizable knowledge about what types of systems and implementation methods will improve care. Also the types of ICT systems that will help with managing costs for specific health organizations still require further attention (Shekelle et al., 2006).

There are many diverse information systems in use aiming to improve the efficiency of health care services. The lack of state-of-the-art clinical and business technology has affected capital expenditure in health care technology (Mitchell, 1999). Many organizations struggle with the development of standard definitions of metrics with real-time analysis capabilities (Stone-Griffith et al., 2012).

2.2.2 Finland in comparison to other European countries

In April 2008, the European Commission published a report on benchmarking information regarding the use of ICT among general practitioners in Europe (Dobre et al., 2008). Conducted in 2007, the "Pilot on eHealth Indicators" survey covered all the 27 Member States of the European Union at the time, as well as Norway and Iceland. Presenting the outcomes of the survey, the report covered the use of ICT for eHealth purposes by primary care physicians. A similar study providing an overview of how Europe's acute care hospitals use eHealth was published in April 2011 (Stroetmann et al., 2011).

According to the report, Finland has a longstanding history of strategy development and implementation of eHealth in relation to its health system. The Ministry of Social Affairs and Health established its first Strategy for the Utilization of Information and Communication Technologies in Welfare and Health in May 1996 as part of information society policies aimed at facilitating information transfer between organizations. This strategy was built around the principle of citizen-centered, seamless service structures. The main goals of the strategy included the horizontal integration of services (social, primary and secondary health care), as well as the development of shared, coordinated services delivered closer to home.

General practitioners regarded Finland was as one of the frontrunner countries in eHealth use. At the time the study was conducted in 2007, ePrescribing was not available to Finnish GPs. All service providers were connected to the internet, and health information was transferred using broadband networks. GPs used ICT on a daily basis. They used eServices, including the transmission of images, eReferrals, laboratory results and, among other things, ICT in consultations. It was only in the areas of ePrescribing and Emergency Alerting System (EAS) disaster recovery in less than 24 hours that Finnish acute care hospitals were ranked significantly below the EU average.

Finland is currently building a social and health care information administration concept that consists of national information system services and the regional solutions supporting them. The first to be completed was the e-prescription service, and the use of online prescriptions is already part of everyday activities in the public health care sector. The introduction of online prescriptions within the private health care sector is progressing and in 2016 all private sector providers are also using the service.

Finland seeks to create a system where everyone can manage their own patient data, with the aim of every citizen taking a more active role in their own health care. The patient data system should enable every health care professional to access information about the patient's earlier treatment received elsewhere. The aim is that the compiled patient summary will decrease the number of overlapping examinations and ensure information flow to others involved in the care of the patient.

The most common obstacles to the use of information systems in health care include software and hardware prices, operating and personnel costs, and arranging funding. Another obstacle is the fact that it is often unclear whether or not the investment is of any real financial benefit – there is uncertainty about the achievable benefits, concerns about fall in productivity and operating problems, as well as attitudes and apprehensions in general, management and culture problems within the organization, and a lack of business competence (Goroll et al., 2009; Jha et al., 2009; Lorenzi et al., 2009).

3 ICT investments and their assessments in health care organizations

3.1 Economic evaluation in health care

3.1.1 Health care costs

Direct health care costs are the costs of the resources used, such as equipment, medicines and personnel costs. Direct non-health-care costs are incurred through the use of other resources in society and include social services costs and patient travel costs. Direct costs include the most important health care resources used in treatment and the time used for patient care. Indirect health care costs include the future costs arising from treating a health condition, whereas indirect non-health-care costs arise from the loss of production resulting from a health condition.

Economic evaluation considers the direct costs (personnel salaries, the price of an action, medicines, maintenance of facilities, etc.) and indirect costs related to productivity (absenteeism costs, etc.). The dimension of time (to determine when the patient has recovered) is not always clear in the formation of costs and outcomes in economic evaluation. This is why it can be difficult to determine the correct discount rate (Drummond et al., 1997; Garber and Phelps, 2008).

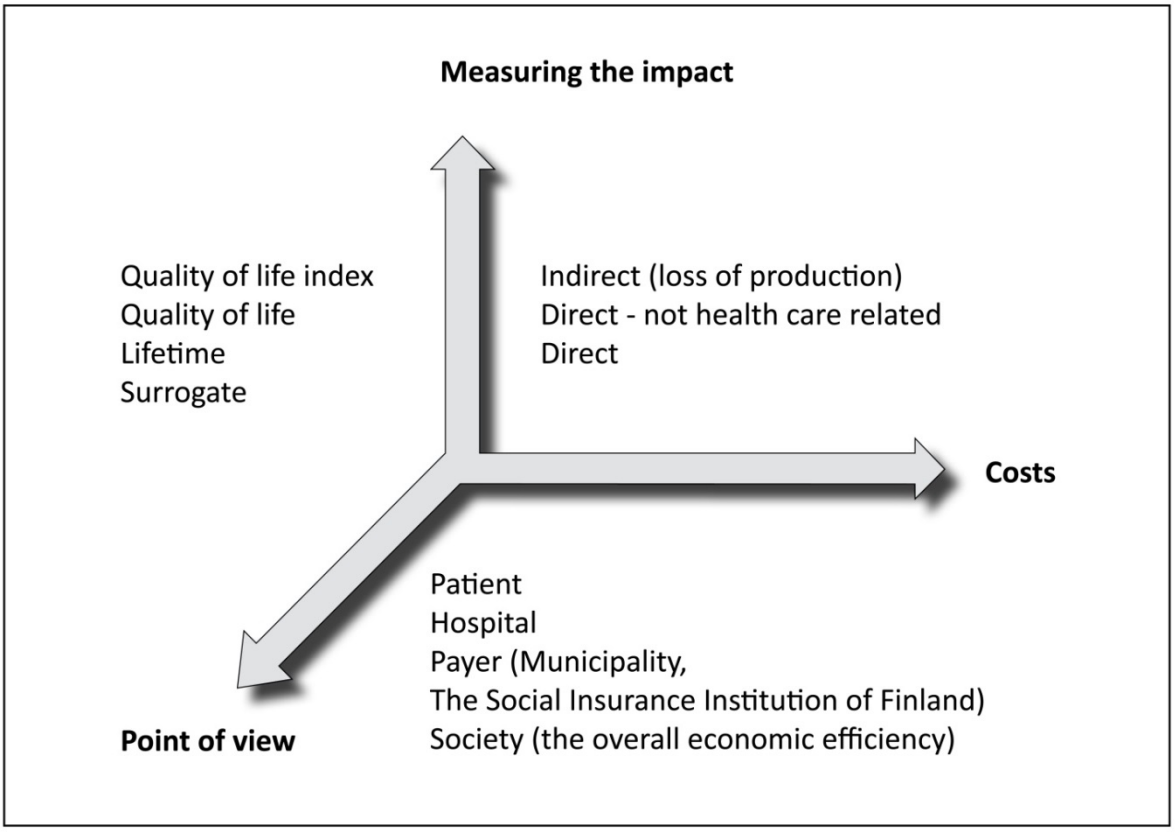

FIGURE 1. Dimensions of the cost-effectiveness analysis (Martikainen, 2008).

The selection of costs often depends on whose perspective is chosen (the health care system's i.e. institution, government, follow-up care, insurance company, the patient and relatives or society) (Fig. 1). The choice of perspective often depends on the stakeholder the assessment is done for and that needs the answer (Johnston et al., 1999; Kulmala et al., 2006). Health care investment refers to capital investments in ICT and forms of treatment that the patient can access.

Although the quality of life is defined by the patient themselves its assessment can be objective. There may be concern about how individuals allocate their resources to produce health (Grossman, 1972). When quality of life is considered in the context of well-being related to health, it is commonly referred to as health-related quality of life (HRQOL). The purpose of HRQOL measurement is to quantify the degree to which the medical condition or its treatment impacts the individual's life (Ferrans, 2005).

3.1.2 Economic evaluation methods in health care

The key approach in the economic evaluation of health care is to identify, measure, value and compare costs and consequences of the alternatives (Drummond et al., 2005). In medicine, economic analyses are carried out to establish the costs of medical procedures and the impacts on the state, status and/or health and quality of life of patients (Drummond et al., 2005; Sintonen, 2007).

Economic evaluations strive for efficiency to achieve operational goals as far as possible within the constraints of given limits (Sintonen and Pekurinen, 2006, p. 250). The types of economic analysis employed are Cost-Benefit Analysis (CBA), Cost-Effectiveness Analysis (CEA), and Cost-Utility Analysis (CUA). Economic evaluations identify, value and measure the various types of costs in the same way in all of these. However, the nature of the consequences (outcomes) of the different alternatives being examined differs between the methods. (Birch and Donaldson, 1987; Drummond and Jefferson, 1996; Drummond et al., 1997; Brown, 2005; Drummond et al., 2005; Sintonen, 2007; Yates, 2009). Cost-Minimization Analysis (CMA) is a special case which only compares alternatives with the same outcome: it is most often used when comparing two products (drugs) that have been shown to be equivalent in dose and therapeutic effect.

The purpose of Cost-Benefit Analysis (CBA) is to aid decision-making by indicating the most viable plan or project choice seen from the perspective of society as a whole, where both costs and all outcomes are valued in monetary terms (Dasgupta and Pearce, 1972, pp.19–22). When planning investments, CBAs can be considered as being an extension of normal investment calculations since they also factor in benefits and costs arising outside the organization. Effective allocation of health care resources and maximum patient well-being are generally acceptable decision-making criteria. The problem is to determine when health care resources have been allocated most effectively and when the well-being of members of society has been maximized. The Pareto criterion defines allocative efficiency as an optimal social state where no one can be made better off without someone being made worse off (Sugden and Williams, 1978). The Hicks-Kaldor compensation criterion was devised to supplement the Pareto criterion to solve conflicts between the different parties. According to the Hicks-Kaldor criterion, an improvement in potential Pareto well-being arising from a plan or project is created if the beneficiaries of well-being can, in principle, compensate the losers' losses (Dasgupta and Pearce,1972, pp.57–61). When using the Pareto criterion or the Hicks-Kaldor compensation criterion, the decision-making process will include large criteria (factors) which are difficult to quantify.

CBA provides an estimation of the value of resources used in each program compared to the value that the resources used might save or create (Drummon et al., 2005). A willingness-to-pay analysis is often used to value health benefits (Pekurinen, 1992; O'Brien and Gafni, 1996; Drummond et al., 1997; Keith et al., 2000). Willingness to accept compensation is used in situations where similarly the willingness to abandon a benefit is evaluated (Kolstad and Guzman, 1999). The best-known method to translate health outcomes into monetary value seems to be the human capital method. This method defines the potential life lost and the loss in wage while the person is not able to work (Cutler and Richardson, 1997).

Since it is difficult to measure the monetary value of all the effects of CBA, the Cost-Effectiveness Analysis (CEA) has been devised. CEA identifies, measures and values all of the relevant costs and benefits/effectiveness of alternative production processes. Costs relate to the resources which must be given up in order to gain some benefits or a desired effect, while benefits are those resources which are gained from the expenditure of other resources used to produce them. These definitions hold for the cost of buying or implementing the technology being assessed and for the health benefit attributable to the technology. In CEA, all net medical/health resource changes are compared with all net health status changes. The analysis treats medical cost savings as negative costs rather than benefits. (Phillips, 2009)

Cost-Utility Analysis (CUA) is very similar to CEA, although the approaches differ by the unit measuring the effectiveness. CUA measures the effectiveness of the different choices in units based on an individual's level of utility. CUA allows comparison across different choices by using a common unit of measure, whereas CEA is only able to compare choices represented by the same measure of effect. When applying CUA, the unit of measure used is quality adjusted life years (QALY). When calculating the QALY, the quality of life is multiplied by the duration of the intervention. In the calculation, the patient's years of life remaining following a particular treatment or intervention are estimated and each year is weighted with a quality of life score (on a zero to one scale) (Robinson, 1993, pp. 859–862; Neumann et al., 2000).

Cost-Minimization Analysis (CMA) is the simplest of the economic evaluation models but also very limited in terms of usability. The method can only be applied when the effects of the action to be analyzed are of the same type and fixed in magnitude (Sintonen and Pekurinen, 2006; Asikainen, 2007). CMA is also used where it is laborious to ascertain the effects or where financial conditions so require. The aim of CMA is to decide the least costly way of achieving the same outcome with a

relevant simple model (Birch and Donaldson, 1987; Drummond and Jefferson, 1996; Drummond et al., 1997; Brown, 2005; Sintonen, 2007, p. 251; Yates, 2009).

When analyzing the benefits of a potential clinical ICT investment, the health care organization should select the method best suited to the particular investment case in question. The selection of the economic evaluation method would also depend on the availability of management accounting information. The cost savings could be viewed as positive cash flow in the investment analyses.

3.1.3 Investment assessment and criteria for investment decision

Health care organizations face the same challenges as other organizations in developing and implementing capital investment strategies (Reiter, et al., 2000; Verho, 2002; Wiberg, 2004; Sintonen, 2007; Sapountzis et al., 2009; Pirttivaara, 2010). There is always uncertainty involved in clinical IT system investment decisions (Smith and Ankum, 1993; Simerly and Li, 2000; Zhu and Weyant, 2003; Verbeeten, 2006).

There are a number of methods commonly used to evaluate investments when making decisions. It is important to understand how to choose an appropriate capital budgeting technique. There are two categories of capital budgeting practices: simple and advanced (Haka et al., 1985; Haka, 1987; Murto and Keppo, 2002; Chatterjee et al., 2003; Miller and Waller, 2003).

The calculation methods usually employed in investment analyses are the Net Present Value (NPV) method, annuity method, internal interest rate method, return on investment (ROI) method and payback method. Real Options Reasoning (ROR) and Game Theory (GT) principles can be used when determining the trade-off between adopting the investment project early and waiting for more information. ROR emphasizes the value of delaying an adoption decision until further information about the investment project is available, whereas GT indicates that firms have an incentive to invest early in case another firm is the first mover and adopts the investment project, thus eliminating the investment opportunities for all the other firms in that industry (Smith and Ankum, 1993; Murto and Keppo, 2002; Miller and Waller, 2003; Zhu and Weyant, 2003; Verbeeten, 2006). Data to measure the benefits and costs for each stakeholder are needed for an economic analysis. Monetary values have to be assigned to enable the evaluation of economic and productivity performance. Economic evaluations provide an estimation of the economic performance over time and show whether investing in a particular system has a positive or a negative economic impact. The net benefit derived from the economic evaluation can be viewed as the potential saving (Stroetmann et al., 2006).

The ranges of different risks across the different projects that an organization considers affect the capital budgeting method selected (Schall and Sundem, 1980). There are three types of uncertainty which impact capital budgeting practices: general uncertainties, industry-specific uncertainties and organization-specific uncertainties (Miller, 1992). Large companies have more resources and often tend to use more sophisticated capital budgeting practices than small companies when evaluating investments for decision-making (Chenhall and Lagerfield-Smith, 1998; Farragher et al., 2001; Williams and Seaman, 2001).

Capital budgeting practices vary from one industry to another: ROR and GT are more commonly used in the financial services industry and in high-tech industries (Billington et al., 2003; Zhu and Weyant, 2003; Verbeeten, 2006). NPV is largely used where the uncertainty of cash flow predictions can be explored through “sensitivity analysis” of the effect of changing assumptions and riskiness can be incorporated by varying the discount rate (Parker, 1969). When Discounted Cash Flow (DCF) is employed, the cost of capital is frequently exaggerated (Kaplan and Atkinson, 1988). Kaplan and Atkinson urge for more realistic assumptions about the cost of capital, although Primrose (1991) argues that this is seldom a critical factor in decisions. Researchers have indicated that these discounted cash flow methods have shortcomings in analyzing investment projects when information concerning the future investment decision is not available (Dixit and Pindyck, 1994; Verbeeten, 2006). There have been concerns that conventional accounting does not provide relevant results when making investment decisions concerning various kinds of technologies (Jones and Lee, 1998). Traditional accounting methods may result in engineers trying to justify investing in the wrong technologies for the wrong reason. In order to avoid this, all the advantages of technology should be included in an investment appraisal (Primrose, 1991). At the strategic level, it is difficult to measure direct return on investment (ROI) that supports the achievement of service, satisfaction, and in the health care sector, the quality-of-care goals.

Public health care can benefit from using capital budgeting practices. This way the investment assessment and calculations do not take into account the cost of capital. This simplifies the investment assessment process, whereas in a publicly-funded organization the cost of capital is not such a relevant factor.

3.2 ICT investments in health care

3.2.1 Evaluation of a health care ICT system

Decision-making in public organizations takes into account financial, technical and functional aspects as well as social obligations and impacts (Pirttivaara, 2010; Forsström et al., 2012). In information and communication system projects, annual costs as a rule typically include license fees, operating and maintenance costs, training costs, outsourced user services, specialist services, overheads and other costs such as telecommunications and leasing payments (Neilimo and Uusi-Rauva, 2005; Wootton, 2009). In investment decision-making, the following factors should also be taken into account: the financial and human resources available (budget financing, personnel) and their expected development, the qualitative and quantitative service needs of patients and the technological, functional and financial risks relating to the existing system (Jenkins and Christensen, 2001; Lillrank et al., 2004; Smoldt and Cortese, 2007; Pirttivaara, 2010). In most cases, investment decisions and their priorities in public health care are driven by external factors such as legislation, regulations and administrative provisions or other similar obligations (Pirttivaara, 2010).

Evaluation of a health care information system involves measuring or exploring properties that serve decision-making (Ammenwerth et al., 2004). In the evaluation and selection process, all variables are collected on their merit and worth by comparing alternatives and ultimately making the choice (Guba and Lincoln, 1981; Berghout, 1997). Health care information system evaluation methods can be divided into the formative-summative and the objectivist-subjectivist methods (Friedman and Wyatt, 2006). The formative type of evaluation is conducted during the lifetime of a project and is intended to provide input for development and design, whereas the summative type of evaluation is conducted at the end of a project and is intended to identify what the system achieves (Laerum, 2004; Stoop, 2005). The objectivist method consists of quantitative measurements, whereas subjectivist methods deal with qualitative measurements.

In the evaluation process, the rapid change and development of technologies may be assessed at different stages of diffusion and maturity in order to meet the needs of various policy-makers (Goodman and Ahn, 1999). To capture the benefits of new technologies, appropriate evaluative dimensions that take into account indirect benefits and costs are needed to enhance decision-making within health care organizations (Sorenson et al., 2008). Evaluation should incorporate the opinions of all major stakeholders and focus on a full range of benefits or outcomes, both tangible and intangible, i.e. process changes and the accompanying ICT investments (Remenyi et al., 2007).

Clinical ICT systems can be evaluated on the basis of their type of objectives or the problems addressed and can be classified as follows: infrastructure requirements, operational performance objectives and strategic objectives (Sims, 1999). Systems are generally intended to address operational performance objectives, strategic objectives, or both. Systems are likely to generate value if they support operational performance and strategic objectives that are reflected in these clinical processes (Sims, 1999). They enable process improvements to be made that would not have been possible without the new ICT. The acquisition process should involve planning and decisions related to the changes in the operational processes. This must be taken into account in the decision-making process. The potential benefits of new technologies, the utilization of new, more efficient processes and methods, with appropriate evaluative dimensions that take into account indirect benefits and costs, are needed to enhance decision-making within health care organizations (Sorenson et al., 2008).

3.2.2 Aspects influencing clinical ICT investment decision-making

The health care industry is typically characterized by a climate of continuously changing legislation and organizational and operational structures, and also by the opportunities brought about by ICT. These changes also bring challenges in the choice of information systems. The connectivity of a system to existing systems and any future systems must also be weighed up when considering the various choices available. Examination of the investment cost of a health care information system must also take into account process efficiency, i.e. the impact of the systems on the organization and working practices (Pohjola, 2008). There may be costs and savings in the organization in question and in other organizations, as well as individual costs and savings for the patient. The complexity level in implementing health care information systems is also exceptionally high, and there are many determinants affecting success or failure (Brender et al., 2006).

Also standards and architecture can impact the costs of health care information systems because system interoperability is still a major challenge (Kleinke, 2005; Jha et al., 2009; Kern 2009; Ludwick and Doucette, 2009). An examination of the investment must cover the lifecycle of the entire system, the phasing out of the old system, migration to the new system and connection and integration with other systems (Stroetmann et al., 2006). In health care, the lifecycle of ICT systems could be years or even decades, while political oversight changes more rapidly. This will affect the predictability of a public health care organization’s strategy.

Investment calculations can also result in an organization deciding to outsource, incorporate or privatize functions or to buy services from outside the organization. In health care investment decisions, it is assumed that the investment can be recouped, i.e. the payback time is shorter than the system's operating time. Especially in public organizations, the financial yield requirements might be modest (break-even budget, etc.).

The financing costs of an investment must be examined as part of the resource audit (Garrido et al., 2005; Kaushal et al., 2005; Walker et al., 2005; Goldstein and Groes, 2006; Garber and Phelps, 2008; Goldzweig et al., 2009). Most public health care organizations will receive their financing through a public sector budget. Public health care also needs to find innovative ways to fund information system projects. This is why financing costs are increasingly more important in public health care information system projects.

A clinical ICT (healthcare technologies) investment decision is approached from an economic evaluation perspective in which all relevant costs, i.e. fixed as well as variable, should be identified, however, keeping in mind not to overburden the trial data collection process with the gathering of too detailed information (Williams et al., 1995; Drummond and Jefferson, 1996; Johnston et al., 1999). At the same time, benefits are identified from the respective stakeholders' point of view, i.e. patients, doctors, insurance company, tax payers, healthcare provider organizations, and any other third party payers (Martikainen, 2008). The selected economic evaluation method focuses on measuring potential net economic gains. These economic gains are the difference between the economic values of direct benefits deducted from the identified costs. An ICT investment should be evaluated in the same way as any new drug or treatment in order to prevent the decision becoming too greatly influenced by political, economic or social circumstances (Catwell and Sheikh, 2009).

The Finnish health care system is in a very interesting phase. There are many ICT system projects underway in Finland, both in the private and the public sector, which aim to integrate different organizations' systems to make them interact with each other as a single entity. Currently there is much discussion about how ICT can be used to enhance service provision and how services should be developed when considering the entire health care reform now ongoing.

4 Contingency theory

4.1 Health care organization from the contingency theory perspective

From the contingency theory point of view, hospital cost-system design has been found to vary systematically with internal, organizational variables, and external, environmental variables (Counte and Glandon, 1988; Lawrence, 1990; Fisher, 1995; Hill and Perry, 1996; Chapman, 1997; Otley, 1999; Hill, 2000; Spekle, 2001; Ferreira and Otley, 2005; Gerdin, 2005; Huikku, 2007; Merchant and Otley, 2007). Pizzini (2006) grouped the determinants of a hospital cost-system design into three categories: strategic, structural, and environmental. Pizzini tested the relations between managers' beliefs about cost data and actual financial performance, and both the absolute level of cost-system functionality and the extent to which cost-system functionality is aligned with a hospital's strategy, structure and environment. The managers' evaluation of the relevance and usefulness of cost data correlates positively with the extent to which cost-systems can provide greater cost detail, better classify costs according to behavior, and report cost information more frequently (Pizzini, 2006).

While health care providers are facing increasing pressure to provide high-quality and cost-effective care, they are beginning to incorporate accounting processes in order to deliver more value to all stakeholders (e.g. Hopwood, 1984; Häkkinen, 1995; Kaplan and Norton, 1996; Kekomäki, 1997; Paavilainen, 1999; Lowe, 2000; Kaplan and Norton, 2001a; Kaplan and Norton, 2001b; Ittner and Larcker, 2003; Kurunmäki et al., 2003; Kurunmäki, 2004; Lapsley and Wright, 2004). Most health care expenditures are the results of individual health care practitioners' decisions, and it is vital to be able to influence physicians' attitudes towards health care costs (Abernethy and Stoelwinder, 1991; Bloomfield and Coombs, 1992; Abernethy and Chua 1996; Lapsley, 2001; Bovier et al., 2005). In Finland during the early 1990s, modifications were made to the official accounting practices in hospitals in order to improve the cost-consciousness of health care professionals and to provide information for the decision-making process (Kurunmäki, 1999; Van der Geer and Kangis, 2000). The reforms in the Finnish health sector's accounting practices were based on promoting economic values and enhancing the ability of health care investors to employ their economic capital, as well as to change the culture in the management of health care (Mayston, 1993; Kurunmäki, 1999).

4.2 Contingency variables in decision-making regarding clinical IT systems in the health care sector

Contingency theory identifies many variables that might have a role in designing a management accounting system to support a decision-making process. Internal variables cover the organization's strategy, culture, technology, structure and size, whereas external variables cover the organization's operating environment. This dissertation analyzed strategy, culture and technology from the internal contingency variables point of view. How the organization's structure and size would affect the investment decision-making process was not studied. From the external variables point of view, the organization's operating environment and relevant legislation were analyzed.

4.2.1 Strategy as a contingency variable

Strategic priorities should be supported by an appropriate control system and organizational structure (e.g. Anthony, 1965; Mintzberg, 1973; Porter, 1980; Hopwood, 1984; Johnson and Kaplan, 1987; Dent, 1991; Shank and Govindaranjan, 1993; Simons, 1995; Chenhall and Langfield-Smith, 1998; Kaplan and Norton, 2001a; Kaplan and Norton, 2001b; Chenhall 2003). Chenhall (2003) suggested that strategy differs from other contingency variables because it is not an element of content. According to Chenhall, strategy is rather the means whereby managers can influence the nature of the external environment, the technologies of the organization and structural arrangements of the control culture.

Health care differs in many respects from the definition in economics of a fully competitive market because the service users do not directly pay for health care services and there is asymmetry of information between the service user and the service provider. Differentiating between the customer and the provider gives municipalities an opportunity to pursue a completely new operational approach to improve the efficiency of the traditionally functioning municipal organization. Strategy-based management is fairly new in the health care sector, which has been characterized by a bureaucratic and hierarchical operational model (Majoinen, 2001; Silvennoinen-Nuora et al., 2005; Silvennoinen-Nuora, 2010).

A municipality's poor financial performance results in it having to increase revenue either by raising taxes or by more borrowing. In addition to this, the public sector also has a similar role that goes against business trends, where poor financial performance resulting from business trends can lead to a conscious growth or cut in consumption to avoid taking out loans. Municipalities do not have a similarly clear expenditure strategy. Municipalities neither cut nor similarly increase their social and

health care expenditure quickly and systematically when the economy worsens or improves (Vallinvaara, 2008).

A key question arising in the strategic management of municipalities is what information forms the basis for deciding the orientation of municipal services (Silvennoinen-Nuora, 2010). The principle of a need for a holistic approach in evaluating effectiveness with the help of a balanced set of measures is especially important in public organizations in particular, which lack an evaluation framework derived from the markets (Lumijärvi, 1994; Lumijärvi, 1999; Lumijärvi, 2002; Niven, 2002; Niiranen et al., 2005a; Niiranen et al., 2005b; Rannisto, 2005; Silvennoinen-Nuora, 2010; Vohlonen et al., 2010). The importance of a multi-dimensional evaluation according to a balanced set of measures is that political value choices and priorities can be built on factual information provided by the evaluation (Lumijärvi, 1999).

4.2.2 Organization culture as a contingency variable

According to Drucker (1992), organizations need to distinguish between habits and culture. Flamholtz et al. (1985) defined organizational culture as “the set of values, beliefs and social norms which tend to be shared by its members and, in turn, influence their thoughts and actions” (p.158). Key success factors are those activities, attributes, competences and capabilities that are seen as critical pre-requisites for the success of an organization in its industry at a certain point in time (Dent, 1991; Pratt and Beaulieu, 1992).

Adopting a broad perspective of management control implies that organizational culture and structure are a means rather than mere premises of control (Flamholtz et al., 1985; Merchant and Van der Stede, 2007). While the mere existence of any organizational culture and/or structure affects organizational behaviors, they are also objectives of deliberate managerial actions. They are designed and adapted to affect the behavior of organizational members in the attainment of organizational strategies and goals, irrespective of whether these strategies are ex-ante planned or merged (Mintzberg et al., 1998).

Efforts in cultural competences can reinforce hospitals’ mission, facilitate the achievement of strategic priorities, such as expanding market research, help institutions to increase patient and employee satisfaction and improve the quality of care. Integrating cultural competences into organizational priorities and processes requires commitment, determination and resources. Leaders

play an important role in transforming organizations through specific actions (Kotter, 1995; Dansky et al., 2003; Kochan et al., 2003; Reelder et al., 2006; Wilson-Stronks and Mutha, 2010).

Even where managers' main concerns focus on clinical and financial outcome, they have realized that cultural issues are also strategically important competences. This makes diversity and cultural competence efforts highly relevant for all leaders interested in improving clinical outcomes and patient safety (Smedley et al., 2003; Karliner et al., 2007; Newman and Davidhizar, 2007).

The basic interface of technology and organization should be considered within the context of organizational culture, a fundamental set of assumptions, values, and ways of doing things that have been accepted by most of its members (Laudon and Laudon, 1995, p.10). Organizational culture can also be regarded as a critical variable affecting change and the achievement of effective and efficient information systems (Ritchie, 1997).

In addition to their internal cultural issues, health care organizations also need to consider cultural competence from the patients' point of view. This is essential in order to understand patients' perspectives of medical care. In many countries, cultural competences are also embraced for regulatory or legal reasons. To provide high-quality and equitable care, hospitals need to know who they serve and tailor their clinical and administrative services to meet the specific needs of patients and communities. Cultural competences in health care organizations are based on an understanding of the needs of patients and communities and are driven by data verifying the impact of efforts to improve care. Equitable care is increasingly relevant today as hospitals are serving patients with increasingly diverse cultural and linguistic needs. Managers of healthcare organizations emphasize that they embrace cultural competence efforts because doing so is consistent with their mission or strategic plan (Wilson-Stronks and Mutha, 2010).

4.2.3 Technology as a contingency variable

The technological contingency variable includes the nature of the production process, its degree of routine, how well means-end relationships are understood, and the amount of task variety (Emmanuel et al., 1990). More standardized and automated process technologies are served by more traditional, formal management control systems with highly developed process controls (Khandwalla, 1972), high budget use (Merchant, 1984), and high budgetary controls (Dunk, 1992). Less tight use of budgets is more frequently found in less automated, less predictable batch type of production – such as in health care organizations.

4.2.4 External environment

The environment is a powerful variable and plays a key role in organizational contingency research (Young, 2001). Issues such as market uncertainty, competition toughness or type have been put forward as environmental contingency factors (Otley, 1980, p. 415; Anderson, 1995; Hoque, 2001). Uncertainly is also usually understood as an organization's inability to accurately predict production technologies, customer preferences, deregulation and globalization, government regulation and industrial relations (Hoque, 2001). Those changes influence managers' perceived environmental uncertainty, i.e. the top managers' perceived inability to predict accurately an organization's external environment (Milliken, 1987; Tymond et al., 1998; Young, 2001; Henri, 2010).

According to Chapman (1997), it is not relevant, however, whether or not the uncertainty facing a company is caused by the variables referred to above. Instead, what is more important is to recognize uncertainty and the predictability of the decisions made and to be made. This is important because effective control systems depend on their environment and their reliability is contingent on environmental conditions (Khandwalla, 1972; Gordon and Narayanan, 1984; Chenhall, 2003, pp.137–139). When the environment is perceived as uncertain and the future unpredictable, organizations try to get more information for planning, including financial simulation models (Burns and Stalker, 1961; Lawrence and Lorsch, 1967; Duncan 1972; Galbraith, 1973; Chenhall and Morris, 1986; Ezzamel, 1990; Young, 2001).

The more hostile and turbulent the external environment is, the greater is the reliance on formal controls and emphasis on traditional budgets (Chenhall, 2003). Companies operating in a stable business sector may be more likely to use sophisticated capital budgeting techniques (Chen, 1995), and they may also gain higher benefits from using such techniques as compared to companies operating in dynamic business sectors (Haka, 1987). A volatile business sector may drive companies towards a greater emphasis on strategic consideration (Chenug, 1993), although the formality of their strategic analysis may be influenced by business sector dynamism (Mintzberg, 1994; Eisenhardt and Sull, 2001). There is a positive relationship between the adoption of a cost system and increased competition in the hospital sector (Young and Pearlman, 1993; Hill and Perry, 1996; Hill, 2000). TABLE 4 summarizes the contingency variables examined in this dissertation and what is known about each of them from a health care organization's point of view.

TABLE 4. Summary of the contingency variables examined in this dissertation.

Variable	The variable from the health care organization's point of view
Strategy	Health care differs in many respects from the economic definition of a fully competitive market because the service users do not directly pay for health care services and there is asymmetry of information between the service user and the service provider.
Culture	Cultural competences in health care organizations are based on an understanding of the needs of patients and communities and are driven by data verifying the impact of efforts to improve care.
Technology	Health care is increasingly dependent on ICT, but the accumulation of data has outpaced the capacity to use it to improve operating efficiency, clinical quality and financial effectiveness. The implementation of technology has an impact on the health care organization's service (work) processes.
Structure	The structure is often inflexible and hierarchical. Organizations are typically politically controlled.
External environment	Large public sector supported with the small but constantly growing private sector. This is a legislation-driven sector with heavy regulation.

5 Results

5.1 Contingency factors which will contribute to investment decision-making

This chapter corresponds to the first research question: "Which contingency factors will, with reasonable accuracy, contribute to the investment decision-making process when selecting a clinical ICT system in public health care?"

There are many situations in which investing in clinical ICT systems will result in cost savings to health care organizations (Publications I and II) – telemedicine possibilities should always be considered when technically reliable and feasible from the overall cost point of view (Lamminen, 2001). Technology not only enables health care organizations to improve their operations and the quality of care, but in many situations the implementation of a clinical ICT system will also improve a patient's health care experience by saving time and providing the results faster (Publications I and II).

A reasonable level of accuracy is reached when ensuring that the most common external and internal factors have been analyzed in the decision-making process. Likewise, a reasonable level of accuracy is reached when the organization systematically uses the same contingency variables in its investment analysis.

Decision-making relating to a clinical ICT system begins with an analysis of the technological alternatives and their operational potential (technology variable) (Publication III). Due to the rapid emergence of multiple IT programs, the stability, maturity and applicability of the system should be analyzed in order to determine at which point investment in such technology is reasonable (Publications I and IV). Additionally, due to the number of IT systems, the viability of the system depends heavily on the organization's operating environment. The analysis should emphasize three factors in particular: the possibilities to integrate the system into the existing IT environment, the level of standards (describing system interfaces, diagnostic procedures and hardware, data storage formats, data communication and safety issues, archival issues, etc.) and how well the system will support the organization's overall strategy (Publications I, III, IV and V). While many ICT systems are possible in theory, it should be appreciated that their viability is highly dependent on the organization's operating environment (Publications III and IV). The unique needs relating to a health care organization's ICT requirements must be evaluated because the proper integration of multiple applications is paramount. A health care organization's computing environment consists of several integrated applications. Proper integration is a challenge. According to Publication III, a highly-integrated information system supplied by a single vendor may function better because it is better integrated. A multi-vendor system inevitably will be more difficult to integrate with other systems, and this may limit its usefulness and ability to take advantage of new technological advances. However, a benefit of a multi-vendor system is that it usually readily complies with local standards. Nevertheless, reliance on one vendor will increase the cost associated with creating interfaces to systems not provided by that vendor. System selection must take place on a case by case basis (Publication III).

When selecting a clinical ICT system, it is important to use systems and hardware which employ standards that are easy to implement, limited to describing only one detail or procedure, and which are technically of high quality. The number of technical issues in a large system also requires a lot of interface specifications. With regard to standards, these may describe complete systems, different parts of a system, interfaces in a system or very low-level technical details. According to Publication III, diagnostic processes include different sub-processes and hardware which might have their own standards, standards describing data storage formats, standards describing data communication

and safety issues, archival issues, etc. If there are no common languages between the different parts of a system, creating a multi-vendor system is virtually impossible. Furthermore, as stated in Publication III, there are currently no complete standards covering telemedicine and its integration into other medical information systems.

Although standardization is necessary and generally beneficial to all, there are a couple of challenges associated with it. First, if there are competing standards, adopting the wrong one may prove to be expensive and essentially bind the customer to a single vendor. Second, the standardization process may not be easy since it is not easy to define a good standard. The standard should be clear and unambiguous, easy to implement, limited to describing only one detail or procedure, preferably be freely available, and be technically of high quality (Publication III). Regarding standardization, the legal framework can complicate the adoption of ICT. Many standardization processes are not purely technical ones but also include commercial and political aspects.

The investment decision-making process should also be based on the organization's strategy. The new system has to not only support the organization's ICT strategy but also its overall strategy. In the investment decision-making process, there are also other important variables which have to be taken into account: the organization's culture (Publication II), and legislation and politics (Publications III, IV and V).

Legislation governing privacy issues, licensing, liability, malpractice, compliance, etc. varies from one country to another (Christensen and Remler, 2009). At the EU level, the Medical Devices Directive (MDD, EU Directive 93/42/EEC), is related to the rationale to remove software- or hardware-related faults in the diagnostic chain. It is interesting to compare modern digital diagnostic systems with earlier non-computerized systems. For example, the diagnostic retinopathy workflow used to be carried out with paper photographs and manual archives (Publication IV). Legislation also has a significant influence on the acquisition process (Publication V). The health care sector is heavily regulated, and constant legislative changes impact the decision-making process. Legislation might be the most important variable which not only drives the investment decision but also initiates the need for investing in a clinical ICT system (Publication V). According to Publication V, a change in legislation also drove the decision-making process. In a publicly funded health care organization, politicians exercise significant power over investment decisions.

The organization itself also impacts the decision-making process. The organization's culture influences the degree of innovation for providing health care services. The organization brings a well-justified and prepared investment proposal to decision-makers for their consideration and approval. Also the organization's culture influences how actively management seeks alternative ways of providing health care services. The culture also influences how well the organization can attract and retain competent personnel, and the ways in which the organization keeps its personnel up-to-date in medical knowledge in order to ensure a high level of professional competence (Publication II).

In order to ensure reasonable accuracy, clinical ICT system investment decision-making in a public health care organization should begin with an analysis of the alternative technologies and their operational potential (technology variable). The decision-making process continues with ensuring that the system concerned and the potential change in the health care services following the implementation of the system are in line with existing and any new legislation. Such legislation might also affect the technology variable, which might need to be re-visited accordingly. Since the decision-making process is run by the health care organization's management, the organizational culture influences how the systems are viewed internally, and how much the organization is changing its ways of providing services and thus improving overall efficiency in the organization. The organization's culture also affects how well the possibilities of the new system are integrated into daily operations, as well as how well the project itself will be carried out. Also the effectiveness of a decision-making process depends on the amount of relevant information management is able to provide for the decision-makers, as well as how the final decision will be accepted by the organization (Vroom and Yetton, 1973).

There are very few, if any, studies regarding the effectiveness of clinical ICT investments after they have been implemented. Many investment decisions are based on estimations related to future cost savings or improvements in care processes. Much of the research into investment in clinical ICT systems consists of early phase projects, where the intervention had not yet changed or impacted patient care. However, there are several studies related to clinical ICT systems. Most of these studies consider one particular case and the decision-making related to that case (Publication VI).

5.2 Contextual variables which will enhance the performance of clinical ICT system investments

This chapter corresponds to the second research question: Which contextual variables will, with sufficient accuracy, enhance the performance of clinical ICT system investments in public health care?

The alternative IT technologies (technology variable) are identified and the financial performance of these alternatives is evaluated. In order to ensure that the investment decision will perform well, the final IT system selection should be done after also analyzing how well the alternatives will fulfill the requirements from the viewpoint of the other contingency variables.

When assessing the investment calculation and evaluating the possible alternatives, the required investment itself should reflect the technology (ICT) variables described in Chapter 5.11.
According to the findings in Publications I, II, III and V, assessment of the investment requires the technology factors to be connected to the analysis. The Net Present Value (NPV) method was adapted for the investment analysis (Brealey and Myers, 1988) and a possible application of a modified NPV method is presented in Publication V. This provides evidence that clinical ICT investments in a public health care organization should be modified in the following way:

$$\mathrm{NPV} = -I\frac{1-\delta}{1+\alpha+\beta} + \sum_{t=0}^{N}\frac{R_t}{(1+i)^t} \qquad (1)$$

where
the “standard” NPV variables are:

I – actual cost of the required investment,
N – number of years to take into account,
Rt – net cash flow on year t (excluding initial investment), and
i – discount rate

the modification to account for contingency factors

α – possibility for the system to be integrated into the present and future environments ($\alpha \geq 0$),
β – factor describing the level of IT technology ($\beta \geq 0$),
δ – strategic fit of the required investment ($0 < \delta \leq 1$)

The modified formula for the NPV would take the important contingency factors into account. Admittedly, there is major variability in the determination of the values for α, β, and δ, but the formula shows how quantifying the contextual variables would impact the financial performance investments. The contextual variables will be given numerical values either based on the organization's previous experiences and research data, or based on the organization's own estimations and views. The factors are very sensitive to changes in values, and even a small increase in the values of α or/and β will improve the profitability of the investment. The better the new system interoperates with the existing systems the fewer the other costs, which might not be even planned for, related to the integration. The technology selected does not only mean that the system will be supported and maintained also in the future, but it will also secure the implementation of future changes in the environment and processes. Future studies are needed in order to set the value for factors α and β.

Interoperability, as well as the level of IT technology factors, should be based on recent research data, while the strategic fit factor will be based on the organization's view related to the current strategy, as well as the current situation at hand. When determining the values for α and β, the recent research data should be related to the improvement of clinical effectiveness and to the evaluation of economic and productivity performance. Since the strategic fit will be evaluated according to the organization's own estimations, it is clear that the deviation of that variable will be greater.

When evaluating the required investment, each of the factors should be analyzed and evaluated using several detailed elements identified during the investment assessment process. The value of each factor should be documented and presented as part of the outcome of the investment calculation.

Also other capital budgeting methods (Publications I and II) can be used as these have been modified to consider the technology factors described above. This means that the required investment should be assessed in accordance with the formula (1). The choice of the capital budgeting method depends on the management accounting systems information available in the organization.

The cash flow analysis should cover the costs from the health care organization's point of view (Publications I and II). The potential savings gained from new ways of operating as a result of using the new ICT have a major impact on the performance of the investment.

According to Publications II, IV and V, other important factors, such as the legislative climate and culture that strongly influence the investment decision in the health care sector, should be considered

in the final investment evaluation. Within a publicly funded health care system, politicians have the power to decide the level of consumption and the allocation of funds among service providers (Kurunmäki, 1999). The organization's own culture (being the first mover when adopting the new technology), the importance of organizational learning and knowledge, as well as the culture of either outsourcing or insourcing will strongly influence the decision-making process (Publication V).

The results are based on a theoretical understanding of contingency theory and on the empirical studies (Publications I, II, III, IV and V) of cost-analysis in telemedicine and clinical ICT investment studies in public health care organizations.

To summarize, investment decision-making starts by analyzing the technology variables. The technology variables together with the organization's strategy serve as the basis for the financial analysis of the investment. The final decision regarding the investment will be complemented by ensuring that legislation and the organization's culture also support decision-making. TABLE 5 summarizes the research design and the key findings of each of the Publications.

TABLE 5. Summary of the key findings of each of Publication and how they relate to the research questions in the dissertation.

Publication	Research design	Key findings of the Publication	How the Publication relates to the research questions
Teleconsultation: changes in technology and costs over a 12-year period	Would time have changed the financial analysis made 12 years ago and how have cost factors changed since then?	The previous telemedicine cost analysis is still valid, but over time the price of hardware, software and telecommunications has decreased. The limited number of implementations is precisely due to organizational reasons, not technical ones.	Investing in clinical ICT systems will bring cost savings to health care organizations. The choice of the capital budgeting method depends on the management accounting systems (information available).
Economic Evaluations in Teleophthalmology	The aim of the study was to identify the strategic level decision-making and how the knowledge from other business sectors could be used to create a	The cost analysis is only one part of the evaluation process in telemedicine. The relevance of the investment in the health care organization's	Technology not only enables health care organizations to improve their operations and the quality of care, but in many situations the

	decision-making model for health care organizations.	processes must be evaluated as well.	implementation of a system will improve the patient's health care experience.
Integration in telemedicine	When moving the investment decision-making toward more operational issues, the first question relates to technical matters such as standards.	When purchasing clinical ICT systems, interfaces and standards have a very important role, because compatibility is also an important financial dimension.	Investment decision-making in a public health care organization begins with an analysis of the technological alternatives and their operational potential.
The EU medical devices legislation in diabetic retinopathy screening	Creation of and compliance with the rapidly evolving field of technical standards and regulations is at times difficult. It is not always clear where all the standardization extends.	A concrete example of the scope of the EU Medical Devices Directive is the application of a diabetic retinopathy screening system.	Due to the rapid emergence of multiple IT programs, the stability, maturity and applicability of the system should be analyzed in order to determine at which point the investment in such technology is reasonable.
Decision making process for clinical IT investments in a public health care organization – contingency approach to support the investment decision process.	The aim of the study was to find a practical tool which is able to take the different financial and non-financial factors into account. The usefulness of the contingency theory was evaluated.	Investment decision-making in a public health care organization starts with an analysis of the technology variables. The technology variables together with the organization's strategy serve as the basis for the financial analysis of the investment. The final decision regarding the investment will be complemented by ensuring that legislation and the	The contingency theory offers excellent opportunities to take into account various relevant contextual variables in decision-making.

		organization's culture support decision-making.	
Literature review of patient record structures from the physician's perspective	This literature review was carried out using scientific methods when finding out what is known about the structured recording and its benefits for clinicians. This will have a significant impact on practical work and use of time.	The data structures of the information systems used are of considerable importance in medicine in treatment and care processes. Literature does not give an unequivocal answer to the question of the point of view of recognizing the most effective treatment. In addition, a recording is so important to the work process that it should always be taken into account as part of the whole process, not a standalone issue.	There is a lack of data and research related to the overall ICT systems in use in public health care as well as the effectiveness of the ICT systems purchased. Many clinical ICT investment decisions are based on estimations related to future cost savings or improvements in care processes. Much of the research into investment in systems consists of early phase projects, where the intervention had not yet changed or impacted patient care. However, there are several studies related to clinical ICT systems. Most of these studies consider one particular case and the decision-making related to that case.

6 Discussion

6.1 Contributions and implications for future research

There is growing recognition regarding the potential benefits of ICT in health care (Schweitzer and Synowiec, 2012) and these technologies are instruments in strengthening the Finnish health care system (Publications I and V). Debate about whether the potential benefits and savings of ICT can be realized on a large scale since relatively little is known about the economics of ICT in health care (Schweitzer and Synowiec, 2012) is also increasing. The following statement illustrates the importance of this dissertation: There is no clear decision-making model to assist in structuring clinical ICT system investment decisions in health care organizations (Southard et al., 2012). Prior to this work, there was a lack of scientific literature addressing the decision-making model and investment analysis, beyond cost-analysis, to assist in structuring clinical ICT system investment decisions (Pirttivaara, 2010; Southard et al., 2012; Schweitzer and Synowiec, 2012). According to Publication VI, there is also a lack of data and research related to the overall ICT systems in use in public health care organizations.

This dissertation provides two main contributions to the academic community:

- Identifying the use of contingency theory in clinical ICT investment decisions in a public health care organization from a management accounting perspective; and
- Conducting a theoretical exercise aiming to identify and analyze the contingency variables which may contribute to the investment analysis when investing in clinical ICT in a public health care organization.

The first research question (Which contingency factors will, with reasonable accuracy, contribute to the investment decision-making process when selecting a clinical ICT system in public health care?) contributes to the investment *decisions* when investing in a clinical ICT system in public health care organizations. Research into this topic primarily relates to the improvement of individual treatment or the organization's patient care processes.

Previous studies show there to be no clear decision-making model when investing in ICT systems in public health care organizations (Southard et al., 2012; Schweitzer and Synowiec, 2012). Since public health care organizations are increasingly investing in ICT, there is a need to assist such organizations in structuring investment decisions. There is also a lack of research into the effectiveness of the ICT system after the investment decision has been made (Publication VI).

Furthermore, there seems to be no evidence (to the author's knowledge) of previous scientific studies identifying the use of the contingency theory in clinical ICT investment decision-making in public health care. The usefulness of the theory is evaluated within the context of a public health care organization's decision-making to invest in a clinical ICT system.

From the contingency theory point of view, there are several studies related to hospital cost-system design, which systematically varies according to internal organizational factors and external environmental factors (Counte and Glandon, 1988; Lawrence, 1990; Hill and Jones, 1992; Fisher, 1995; Otley, 1999; Hill, 2000; Spekle, 2001; Ferreira and Otley, 2005; Gerdin, 2005), but these studies do not address the use of the theory in investment decision-making in public health care. However, it could be argued that the conceptualization of investment decision-making, per se, was not the focus of previous studies. Moreover, before this dissertation, most of the authors had studied the performance of large, individual, successfully implemented cases and not the decision-making model as such (Heeks, 2006; Catwell and Sheikh, 2009).

The relevant set of contingency variables which will improve the clinical ICT investment decision was found. The decision-making process should start with an analysis of the alternative technologies and their operational potential, the technology variable. After the selection of the technology, the overall legislation and its possibilities (potentiality) and limitations, as well as the organization's culture, i.e. willingness toward changes, and the overall competences should be analyzed before making the final investment decision. Legislation and the organization's culture variables might also affect the technology variable, which is why the financial analysis might need to be re-visited during the decision-making process. The investment decision-making process should be conceived by analyzing the factors and determining the values for the contextual variables when evaluating the investment alternatives. The contingency theory provides support not only in understanding the factors that need to be analyzed but also the level of relevant value of the variables. During the decision-making process and before making the final investment decision, there should be a constant process also to re-visit and evaluate the earlier decision and analysis and reassess them where needed.

The approach was to operationalize the decision-making process in order to build up a management accounting system to support decision-making processes and to provide feedback on investments. In practice, the decision-making model enables the use of various investment criteria and will thus help the organization to prioritize the relevant factors when evaluating and analyzing the investment

alternatives. It was noted that there are various factors that interact with each other in the process. Legislation and the organization's culture take a central role when investing in clinical ICT systems.

The second research question (Which contextual variables will, with sufficient accuracy, enhance the performance of clinical ICT system investments in public health care?) contributes to the *investment analysis* by introducing financial modification to account for contingency variables in the evaluations of clinical ICT systems. There are several studies related to the cost-effectiveness studies of providing health care services, i.e. the use of ICT systems and telemedicine. Many ICT investment decisions are based on estimations related to future cost savings or improvements in care processes.

Furthermore, there is no evidence (to the author's knowledge) of previous scientific studies identifying the use of the contextual variable in clinical ICT investment analysis in public health care. This modification of the investment analysis method should enable the total effect of the contingency variables to be factored in. Admittedly, there is major variability in the determination of the values of the contingency factors employed in investment calculations, but the formula provides a tool towards quantifying the complex and contingency factors which tend to be qualitative in nature.

Indirect, i.e. social, obligations and financial factors (costs), are used to enhance decision-making when investing in new technology (Goodman and Ahn, 1999; Jenkins and Christensen, 2001; Lillrank et al., 2004; Neilimo and Uusi-Rauva, 2005; Remenyi et al., 2007; Smoldt and Cortese, 2007; Pohjola, 2008; Sorenson et al., 2008; Wootton, 2009; Pirttivaara, 2010; Forsström et al., 2012).

Standards and system architecture impact the costs of health care ICT as well (Kleinke, 2005; Jha et al., 2009; Kern 2009; Ludwick and Doucette, 2009). Decisions to invest in new technology in health care are approached from an economic evaluation perspective in which all relevant costs, i.e. fixed and variable, should be identified (Williams et al., 1995; Drummond and Jefferson, 1996; Johnston et al., 1999; Sintonen, 2007). The selected economic evaluation method focuses on measuring potential net economic gains. These economic gains are the difference between the economic values of direct benefits deducted from the identified costs. Any new ICT investments should be evaluated in the same way as any new drug or treatment in order to prevent the decision becoming too greatly influenced by political, economic or social circumstances (Catwell and Sheikh, 2009).

This study contributes to existing research (investment literature) by describing the relevant contingency variables which will improve the performance of investment decisions when investing in clinical ICT systems in a public health care organization. Three factors in particular should be emphasized in decision-making: standards, the integration potential of the system, and the strategic fit with a health care organization's strategy. These should form the basis of the financial analysis of the investment, which is then made using a modified capital budgeting method taking these elements into account. Health care organizations' strategies affect the willingness to invest in new ICT. Challenges in adopting new technological opportunities related to telecommunication and information technology, i.e. telemedicine, often depend more on organizational than technological issues (Lamminen, 2001). The application of telemedicine should always be considered when this makes sense technologically and is medically tested and approved, and when there will be cost savings for the health care organization (Lamminen, 2001). Technology enables the health care organization to improve its ways of operating and to increase efficiency.

The dissertation also provides a practical contribution. First, this study has generated new knowledge about the ICT investment decision in the context of public health care services. There have been no earlier studies specifically describing ICT investment decisions in public health care, and the specific legislative-, ICT technology- and strategy-related aspects have not been explicitly discussed as part of investment calculations either. This study highlights the need for standards not only at the ICT system level but also at the legislation level in order to ensure that the systems used in the patient care process are safe and approved for medical use. Organizations need this information when developing their ICT strategies. This study also identified various ways to improve the existing level of legislation and standardization. This dissertation illustrated the practical measurement approach in which the possibilities to integrate the systems and process needs to be measured in the decision-making process. Also the importance of ICT strategy for analyzing the possibilities to integrate the system and re-designed processes is introduced and described.

In addition, future research can be identified with respect to understanding the utilization of measurement information during the whole lifecycle of the investment (planning, implementation, maintenance as well as close-down). What kind of information is needed at different stages of the lifecycle and what kinds of decisions need to be taken during the lifetime of the system? Information is also needed in order to analyze when the system should be changed and what the most important criteria for the new system are.

Future research is also needed in order to identify the relationship between the health care organization's management accounting systems and the investment decision-making process. What kind of role does information received from management accounting systems play in the decision-making process? What are the criteria for developing the management accounting systems in health care organizations and how well are clinical ICT investment decision-making information needs taken into account?

The contingency theory should also be tested further on cases in which the independent variables are not aligned symmetrically, thus providing more insight into how the variables interact with each other under less than optimal conditions and creating the opportunity to scrutinize the role of the individual agency more closely.

6.2 Research assessment

6.2.1 Relevance

First, this research can be considered as relevant since the success of ICT systems implementation is an important factor in ensuring productivity in the public health care sector. This dissertation suggests a model to help public organizations prepare investment decisions when investing in clinical ICT systems. This study provides a good basis for future research related to the ICT investment decision-making process and data related to the overall factors affecting the performance of the investment decision.

Second, measuring an ICT investment is problematic in public health care for many reasons, such as output definition. This dissertation describes an approach supported by identified measurable factors for an organization to evaluate whether or not to invest in a clinical ICT system.

Third, ICT as technology has to be evaluated from the investment decision point of view, measuring the most relevant factors which should affect the allocation of resources among competing investment projects. This study defines the assessment for the required investment when using the capital budgeting methods for clinical ICT investments in a public health care organization.

6.2.2 Validity

The validity of a case study can be improved by using multiple sources of evidence for data collection, seeking to establish causal relationships, defining the domain to which a study's findings can be generalized and demonstrating that the operations of a study can be repeated (Yin, 2009).

The data used in the publications have been collected by using multiple ways of collecting data, i.e. collecting empirical material and collecting data through literature reviews. Publication I is based on empirical material, which was collected for an article published in 2001 and is presented in that article (Lamminen et al., 2001a). The same empirical data that was collected for the earlier study (Lamminen et al., 2001a) were used with updated cost information. Data for Publication II were collected by using literature reviews. Publications III and IV were written after the authors had conducted studies related to several clinical ICT system implementations and participated in two different electronic patient health record (EHR) system studies. In Publication V, the contingency variables were studied on the basis of interviews as well as by using comprehensive material collected from the organization.

The study focused on the issues it was intended to, i.e. the role of IT technology in the investment decision and the decision-making process, and the most relevant contingency variables to be analyzed when investing in a clinical IT system in a public health care organization. The validity of the research was enhanced by examining different cases in different organizations. It can be claimed that a possible weakness is that examination at the operational level was limited to a small number of cases in a public health care organization. However, this is typical for any case research due to practical limitations. A factor improving the validity of the results in Publications I and II is that both represent systems in real-life use. There are also several similar studies in which telemedicine has been implemented in order to improve the co-operation between a primary care center and a university hospital. It is obvious that the cases in the first two articles do not represent anything close to the total spectrum of public health care services, but they serve to give a reasonable picture of the level of decision managers need to make. Publications I and II were analyzed and written after the decision had been made, and this increases their validity. However, as demonstrated by the results, an investment decision can be made in a health care organization by using well-established, conventional investment models, and thus investing in telemedicine will bring cost savings. Hence, the validity of the results is at a reasonable level.

The decision-making process is quite similar in all public health care organizations. While the actual details of the decision-making process in public health care organizations may vary to a large extent, there are certain central external factors which create a significant degree of similarity in the process. For example, the purpose of public health care organizations is dictated by legislation, investments need to take public procurement rules into account, the financial aim is to provide as good a service as possible with as little expenditure as possible rather than create profit, and the organization is under political control.

On the other hand, there may be smaller parts of the organization which are very similar to private companies. An extreme example of this would be outsourcing, where the service provider is a private company which aims at generating profit. The company may make investments which are only used by the public health care organization, and in some cases it may be difficult to draw the line between private and public. However, this seldom seems to be the case with large investments; the amount of political control and other factors typical to a public health care organization increases when the strategic importance of the investment grows. Also, ICT investments are typically highly intertwined due to interoperability requirements, and this brings them close to strategic decision-making.

Thus, it seems reasonable to assume that the decision-making process is quite similar – due to necessity dictated by the similarities in the different environments – across a rather wide range of public health care ICT investments.

6.2.3 Reliability analysis

The reliability of a study relates to demonstrating that the operations of the study can be replicated with the same results by another researcher (Gummesson, 2000, p.185; Yin, 2009, p.40). Reliability is also related to whether the data used can be relied on (McKinnon, 1988). Case studies have been criticized for a lack of reliability (Gummesson, 2000, p.88). Despite the challenges of satisfying the reliability criterion due to the case study nature of this dissertation, reliability is examined with specific viewpoints related to the methods used.

Quantitative data were collected by questionnaire, supporting the data for the first publication. In Publication V, the links between the results of data analysis and the interviews can be identified. The participation of other researchers and intense interaction between the researchers should also have a positive effect on reliability. These should reduce the role of the author’s own subjective interpretations. The purpose of the interviews used in this study was mostly explorative, with the

intention to understand the case better. The interviews supported the material collected in the case and in this way provided a deeper insight into the case.

The purpose of the literature reviews and commentary papers in this study was mostly to collect together all the knowledge the researcher has accumulated during the years of study in this field. In the analysis of the material used for Publications III and IV, interpretation by research was used in order to analyze the material, and this inevitability has an effect on the reliability of the results.

Experience from all the studies was of a similar nature, and all the studies discussed investment in ICT in a health care organization from different points of view. This also reflects a satisfactory level of reliability. However, it is likely that additional cases would have provided new information, but it is impossible to estimate whether such new information would have had any significant effect on the outcome.

Overall, it can be stated that the reliability of this study is at a satisfactory level within the limitations of any case study. The different studies with different methods all related to investment in ICT in a health care organization from different points of view, and this should have had a positive impact on the overall reliability of the results.

The generalization of the results of this research may be evaluated from the perspective of public health care organizations in Finland. Even though Ikaalinen health center and HUSLAB have specific characteristics such as size and regional features, there are many similar organizations in Finland. There is potential for generalizing the results concerning public health care organizations. The generalization of the issues related to the standards and system integration may apply as regards similar services in other types of public service and organizations.

This research was carried out in Finland, but it should have potential for generalization in the public health care sector in other western countries. Since many of the articles included in this study have been published or accepted for publication in international academic publications, it may be argued that the results are of wider international relevance. Factors that should be taken into account in generalizing the findings are at least the differences in legislation, decision-making and in managing the organizations.

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Publication I

Teleconsultation: changes in technology and costs
over a 12-year period

By

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Teleconsultation: changes in technology and costs over a 12-year period

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Summary

In our previous study, in 1997, we evaluated the cost of teleconsultations in a primary care centre compared with the cost of the conventional alternative, travelling to the hospital. The results showed that teleconsultations were cheaper than patient travel when the annual workload was more than 110 patients in ophthalmology and 115 patients in dermatology. Using the same method of analysis for 2009 data showed that cost savings would occur if the annual workload was 20 patients in ophthalmology and 17 patients in dermatology. The main differences between the two studies are the reduced cost of the technology (which was based on PCs in 2009) and the increased cost of staff. Both studies show that teleconsultations can be cost-effective in a relatively small health centre. The cost of technology continues to decrease, although the other costs in our break-even analysis continue to increase. However, the usability of technology continues to improve, and this will make telemedicine a more attractive alternative in the future.

Introduction

Health-care systems are under pressure to reduce costs, improve quality and at the same time to improve the quantity of service. Health centres can provide specialist services in three different ways.[1] One way is to have a specialist visit the health centre and another way is for patients to travel to hospital to see the specialist there. The third way is to use telemedicine, so that no one needs to travel.

In a previous study[2] we calculated the costs of telemedicine compared to patient travel. In ophthalmology, the costs were the same for 110 patients; if more than 110 patients required consultation, then telemedicine produced savings. In dermatology, this break-even point was at 115 patients. During the 12 years which have elapsed since the previous study, there have been changes in the technology available for teleconsultation and in the costs. The aim of the present study was to analyse the effect on the cost of teleconsultation.

Methods

We used the same break-even point method as in our previous study. In that study, quantitative data was gathered by the personnel in a health centre.[3,4] Immediately after each consultation a questionnaire was given to the patient, general practitioner and the hospital specialist. The data collected from the questionnaires included the length of time taken for the consultations, the means of travelling to the university hospital in Tampere, as well as the need for an assistant during the transportation. In the videoconferencing cases the patient did not need to travel to Tampere, but six months later a questionnaire was used in order to check with the patient that the decision made during the video consultation was still valid. The cost of transportation was obtained from the statistics from the Social Insurance Institute. The cost of conventional health-care visits was obtained from the price lists of the university hospital. The questionnaires were designed to be simple and time efficient for the patients who completed them.

Cost model

The cost of a teleconsultation depends on a number of factors, some of which are fixed costs, and some of which are variable costs (i.e. proportional to the patient workload). In our previous study the fixed costs were identified as follows:

I = cost of the equipment
M = cost of equipment maintenance

And the variable costs were identified as follows:

S = cost of the specialist
G = cost of the general practitioner
C = cost of telecommunications
P_v = cost of the paperwork

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The cost of a conventional consultation in which the patient had to travel to Tampere was assumed to depend on a number of factors, all of which were variable costs:

T = cost of travelling to Tampere
A = cost of an assistant if needed for the transportation
H = the price which the university hospital charged for one visit
P_c = the total cost of writing a submission for a patient to go to Tampere (the cost of writing the submission at the health centre and the cost of sending the case history to the university hospital in Tampere).

The cost of travelling depended on which method was used and what proportion of patients used it:

$$T_{tot} = p_1T_1 + p_2T_2 + p_3T_3 + p_4T_4 + p_aA$$

where

T_1 = cost of travelling by a bus
p_1 = proportion of visits to the university hospital by bus
T_2 = cost of travelling by taxi
p_2 = proportion of visits to the university hospital by taxi
T_3 = cost of travelling by ambulance
p_3 = proportion of visits to the university hospital by ambulance
T_4 = cost of travelling by car
p_4 = proportion of visits to the university hospital by car
A = the cost of assistance
p_a = proportion of visits where assistance was needed

The time used for teleconsultation and conventional consultations by the specialist was assumed to be the same. The cost of the time spent by a patient in travelling to the university hospital was not taken into consideration.

Break-even point

The break-even point is the number of patients for which the cost of teleconsultations is the same as the cost of conventional consultations.

$$F_1 = f_1n$$
$$F_2 = f_2n$$

where

F_1 = total cost of n teleconsultations
f_1 = cost of a single teleconsultation
F_2 = total cost of n conventional consultations
f_2 = cost of a single conventional consultation
n = number of patients.

Break-even occurs when:

$$F_1 = F_2$$

Results

Cost of equipment, I

During our original study (September 1996 to May 1997) the teleconsultation equipment consisted of a videoconferencing unit (PictureTel Swiftsite), a TV (Panasonic) and a document camera (WE-160/G, Panasonic). The total cost of owning and maintaining this equipment by the health centre and the hospital was € 31,283 in 1997.

In 2009, teleconsultation could be performed using two ordinary office PCs, inexpensive webcams and an Internet connection. As the PC computers are almost invariably already installed, their additional cost is close to zero. The cost of high quality web cameras at both ends of the connection would be less than € 500. In order to maximize the video quality, some special lighting might be required, but it is likely that the hardware cost would be less than € 1000.

Software may represent a more substantial cost. While there are well-functioning free software programs (e.g. Skype) available, security policy or IT support reasons may mandate the use of commercial software. An example of commercial videoconferencing software is Polycom PVX, which costs about € 200 per licence.

For 2009, a total equipment cost of € 2000 appears reasonable. It should be noted that both video and voice quality would be much better than that provided by the videoconferencing units used in the earlier study.

In our previous study we estimated that the lifetime of the equipment would be five years and the annual interest rate for the investment was assumed to be 6%. In the present study we assumed an equipment lifetime of three years and an annual interest rate of 4%.

Cost of equipment maintenance, M

In the original study we assumed that the maintenance cost was 10% of the total investment cost. This cost depends on the amount of IT support required. In the present study the maintenance cost was 25% of the total investment cost, i.e. since the investment cost was low, the relative maintenance cost will be higher

Cost of a specialist, S

The cost of a specialist was calculated by estimating the monthly salary level and adding 50% to cover costs related to social security, insurance, pension and other personnel related expenses.

During the previous study the average cost of a specialist was € 3363 per month. In 2009 the cost was € 5500 per month. Assuming that the specialist would have 144 hours available for patients in each month and that one consultation would take 30 min, each specialist could have 287 consultations in a month, i.e. in 1997 the cost of the specialist's time would be € 17.60 per patient, including

social security, insurance, pension and all other personnel related expenses. The corresponding figure for 2009 would be € 28.70 per patient.

Cost of telecommunication, C

In 1997 an ISDN line was used for telecommunication between the health centre in Ikaalinen and the university hospital. The cost of the line was 0.65 € per patient (30 min per consultation). After the previous study, communication was transferred to the Internet. As health centres can be assumed to have appropriate Internet connections, the line cost would be zero in 2009.

Cost of general practitioner, G

In our previous study, we estimated that the time a general practitioner spent in teleconsultation cost as much as a specialist's time in Tampere.

Cost of writing a submission for a teleconsultation, Pv

The total time spent on paperwork was estimated to be 5 min and in 1997 this cost € 1.80 per patient. According to the salary levels in 2009 the cost of paper work would be € 2.90 per patient.

Cost of teleconsultation

Using the above cost information the cost of n teleconsultations would be:

$$F_1 = I + M + n(S + C + G + Pv)$$

Travel for conventional consultation

For the ophthalmology consultations between September 1996 and May 1997, the answers provided in the questionnaires showed that patients used public transportation in 15 cases out of 24 to reach the university hospital. In six cases the patient used a taxi and in three cases the patients used their own car.

In the dermatology consultations, 13 cases out of 18 used public transportation. In two cases the patient used a taxi and in three cases the patient needed an ambulance.

Cost of travelling to Tampere, T

According to the Social Insurance Institute's price list the cost of travelling to the university hospital in 1997 was € 17.50 by bus, € 108.00 by taxi, € 216.50 by ambulance and € 19.50 by car. These travelling costs were for a single journey to the university hospital.

In the present study, the cost of travelling to the university hospital by bus was € 13.70, € 110.00 by taxi, € 270.06 by ambulance and € 27.00 by car.

In 1997, the average cost of travelling to Tampere in case of dermatology consultation would have been € 60.72 and in 2009 it would have been € 52.12. In 1997 the average cost of travelling to Tampere in case of ophthalmology consultation would have been approximately € 40.38 and in 2009 it would have been € 39.44.

Cost of an assistant if needed for the transportation, A

In some cases there is a need for an assistant for travelling. In our study of ophthalmology consultations, the patient needed another person's assistance in travelling to the university hospital in six cases out of 24. In case of dermatology consultation, the patient needed another person's assistance in travelling to the university hospital in 11 cases out of 18. The cost of assistance was calculated by using the general per diem allowance, which in 1997 was € 25.20. The same cost in 2009 was € 36.00. No extra travelling costs were taken into consideration while calculating the cost of assistant. An assistant was not needed when a bus was used.

Price which the hospital charged for one visit, H

There is a consultation price list which determines the price paid by the health centre to the university hospital. The price of the consultation is fixed and is charged by a visit. In ophthalmology the lowest consultation price in 1997 was € 75.68 and in 2009 it was € 65.00. In 1997 the price of a dermatology consultation was € 63.30 per visit and in 2009 it was € 72.00.

Cost of writing a referral for a patient to go to Tampere, P_c

When sending a patient to the university hospital, it took about 5 min for a doctor in Ikaalinen to write a referral. A secretary typed the referral and processed it in approximately 5 min. The total time spent on paper work was estimated to be 10 min and the cost of this was € 3.60 per patient in 1997. In 2009 the cost was € 5.90 per patient.

Cost of conventional consultation

Using the above cost information the cost of n conventional consultations was:

$$F_2 = n(T_{tot} + H + P_c)$$

Break-even

The relation between the cost and the workload, for both ophthalmology and dermatology consultations, is shown in Figures 1 and 2. In 1997, cost savings occurred when there were more than 110 ophthalmology teleconsultations annually. The break-even point according to the 2009 data

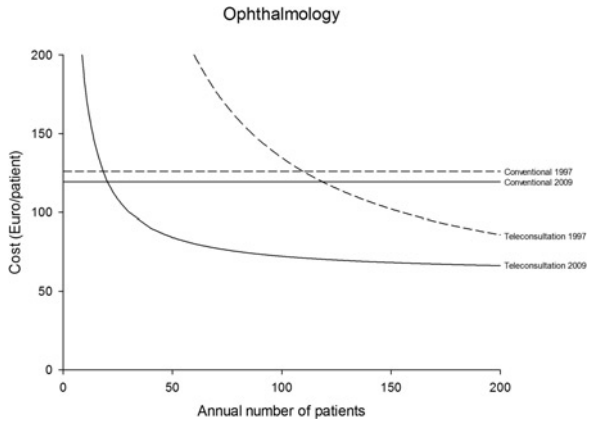

Figure 1 Break-even points for ophthalmology consultations in 2009 and in 1997

would be 20 teleconsultations annually. In case of dermatology consultations a saving occurred in 1997 if approximately 115 patients annually used telemedicine and the break-even point using the 2009 data would have been 17 consultations in a year.

The major difference between the two specialities is the travelling cost. Savings achieved through teleconsultations mainly consisted of reduced transport costs. From the patients' point of view, travelling to the hospital is also costly and inconvenient, while it takes time. If the transportation needed in order to get a patient to the hospital is an ambulance, and if the situation is not an emergency, teleconsultation should always be used first.

The major differences between the two time periods, 1997 and 2009, are the cost of equipment and the cost of personnel. There have been significant developments in technology and the prices of equipment have decreased substantially. On the other hand, salary levels for health-care staff have increased substantially during the 12-year period. A significant contributing factor is inflation. Another factor is the difficulty in recruiting professionals to work in the public sector.

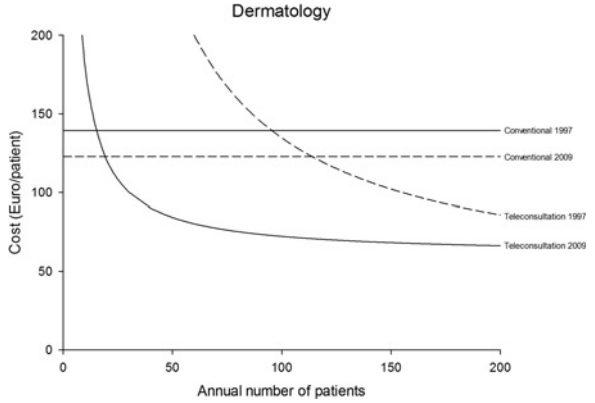

Figure 2 Break-even points for dermatology consultations in 2009 and in 1997

Discussion

For the present study, we used the case study research method.[5] Case studies are useful for providing an understanding of different kinds of organizational functioning, particularly those which are not well documented and are not amenable to investigation through knowing the organizations. It is also possible to confirm findings from other studies using the case studies method.[6] Case studies provide an opportunity to use more than one method of data collection.

Break-even analysis is a simple tool to support investment decision-making. The major limitations in the break-even method are that fixed costs are assumed to be constant and variable costs are assumed to be constant per unit. In the present study, break-even analysis was used to calculate the number of patients at which an investment in telemedicine would be reasonable. The model did not take into consideration factors such as inflation and the result would have been even more in favour of telemedicine if it had.

Our study in 1997 showed that investing in telemedicine would be beneficial for health centres. It can help a health centre accomplish its goals by managing work processes, thereby providing its patients with the best care – telemedicine will save patients the time and expense associated with travelling to the university hospital. Although there have been many studies about the benefits of using telemedicine, it is still not used in the mainstream.

As technology continues to improve, so will the sophistication of telemedicine. Older technology was clumsy to use and training was required. Significant changes to long standing practices, processes and ways of taking care of patients were often required. Present day technology is a commodity – the same tools and equipments are widely used in everyday life. This development will help the adoption of telemedicine in the future – the amount of training required will decrease since health-care practitioners will largely be familiar with the technology. The Internet provides easy access to data, but also represents a fast and cost-effective way of delivering and transferring data. Mobility will continue to increase in telemedicine and make the processes even faster and easier to use.

The health sector has constantly been under pressure to find more cost efficient ways of executing its processes and services. One possibility, which is frequently discussed, is outsourcing. We define outsourcing as: identifying a health-care centre's functionality which is not seen as core competences or service processes and handing over this functionality to a partner.[7] The partner will work together to perform the functions which previously were carried out by the health-care organization itself. This definition is close to the generally accepted definition. Many health centres are investigating outsourcing possibilities. Telemedicine can in principle be used in outsourcing.

The cost of technology continues to decrease, although the other costs in our break-even analysis continue to increase. However, the usability of technology continues to

increase, and this will make telemedicine a more attractive alternative in the future.

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Publication II

Economic Evaluations in Teleophthalmology

By

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Teleophthalmology. Springer-Verlag. Chapter 10, 2006, pp. 71–76.

Publication III

Integration in telemedicine

By

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Journal on Information Technology in Healthcare. Vol. 3, No.4, 2005, pp. 236–238.

INVITED COMMENTARY

This paper by Brauchli and colleagues illustrates some of the diverse applications and benefits that can be achieved with telemedicine. While many applications are possible on the concept level, it should be appreciated that their viability depends heavily on the computing environment. Successful applications require all patient data and images to be transmitted or to be viewed as a single and complete entity. Achieving this in practice requires system integration and the development and application of standards.

The term "integration" essentially means "to put something together". Standards and integration are often discussed together. However, integration does not necessarily need standards. A highly-integrated information system supplied by a single vendor may not comply to any standards, but function better than a multi-vendor system compliant with several standards. Inevitably, however, the single-vendor system will be difficult to integrate with other systems and this may limit its usefulness and ability to take advantage of new advances in technology. To enable different systems to integrate and carry out tasks or specify technical details, regardless of where they have originated, standards are essential.

National standards are issued by official international bodies, but companies or professional associations may also issue recommendations or standards. These unofficial standards may sometimes be more important than official standards. For example, the specifications behind the Internet are called RFC (Request For Comments) and are issued by IETF (Internet Engineering Task Force) which does not have any official status. There are also *de facto* standards which essentially refer to things being done in a certain way because everyone else does it that way. The strength of a standard is not necessarily related to its technical quality or the standardisation body behind it. The most important factor is usually the penetration of the standard. In practice, some rather inferior and non-official standards are very strong because they are very widespread.

Standards may describe complete systems, different parts of a system, interfaces in a system or very low-level technical details. In order to fully describe an integrated medical information system, a large number of standards are required. There have to be standards describing diagnostic procedures and equipment, standards describing data storage formats, standards describing data communication and safety issues, archival issues, etc. The number of technical issues in a large system requires a lot of standards. Standardised interfaces are required for system integration. If there are no common languages between different parts of a system, making a multi-vendor system is almost impossible.

It is not possible to simply specify that the system has to comply to Standard ABC, all relevant interfaces have to be specified. Some standards actually include several independent standards. DICOM[1] (Digital Imaging and Communications in Medicine) is one of these, as different parts of the DICOM standard describe different levels of a system. So, when something is "DICOM-compliant", the question

is whether it complies to the complete set of standards or just one part of it. Consequently, a vendor's claims that its product complies to a specific standard does not provide reassurance that it will integrate within a system.

Although standardisation is necessary and generally beneficial to all, there are some risks associated with standards. If there are competing standards, adopting the wrong one may become expensive and essentially bind the customer to a single vendor. Avoiding this may be very difficult if there are no previously existing strong (i.e. widely adopted) standards in the field. Another risk is associated with a poor standardisation process. This presents a particular problem when the process concerns large economic gains. In this situation the result of the standardisation process may be a compromise rather than a technically good solution to the problem in hand. If standards are complicated and wide they may be difficult to comply to, and this may affect system costs. In some cases, standards have been 'watered down' to the point where different pieces of equipment complying to the same standard are not interoperable. Also when standards specify rapidly changing technical details, they tend to be very weak.

To date, standards in telemedicine have tended to focus on hardware and software, but standards are also desirable for the preparation and presentation of data. The importance of this is illustrated in this paper where one use of the data is for research purposes. To maximise the use and benefits of such data it is necessary that all relevant parameters are available for all patients. For example, for epidemiological studies, relevant data may include age, sex, ethnicity, marital status, occupation, smoking history, etc. Inevitably, as with all studies, the challenge is to collect as much relevant data as possible without making the task of collecting or obtaining the data unduly onerous.

Another important reason for standardising the preparation of data is to enable consistent and reliable interpretation. The need for this can be appreciated better by considering as an example the application of telemedicine to ophthalmological examinations. Fundus cameras can incorporate a standard digital camera capable of producing standard JPEG (Joint Photographic Experts Group) files. In this sense there are standards associated with the process, but there are many missing 'links'. The first problem is that the actual taking of a fundus image is not standardised. There are no common rules for illumination, colour balance or resolution[2]. Another very important missing specification is the compression level of images[3]. When these standards are lacking, the comparability of images taken in different places and with different equipment is poor. Specifying a certain fixed resolution is not a viable idea due to rapid advances in technology. However, the resolution can be defined by some details of the object itself. For example, the resolution of a fundus image could be defined so that a detail the size of a red blood cell has to be discernible in the fundus image. This definition can then be applied to any future system, as well.

The compression level could also be specified without binding the system to any specific file format or program. If the minimum size (in bytes) of the compressed

image is specified, then the amount of detail is fixed. If the number of pixels increases, the compression level can be increased to give the same file size. With the advent of new compression schemes the amount of detail may increase but not decrease from the current situation.

At the moment the most relevant standard concerning imaging is the DICOM standard. However, currently it does not give very specific information on all medical applications. The DICOM working group 9 (WG9) does work actively to address this situation, but the commitment of equipment manufacturers remains to be seen. Whereas DICOM works on the technical details, the HL7[4] (Health Level 7) group is working on the high level integration of different healthcare applications. IHE[5] (Integrating the Healthcare Enterprise) is an organisation promoting the use of HL7 and DICOM standards.

It is not an easy task to define a good standard. The standard should be clear and unambiguous, easy to implement, limited to describing only one detail or procedure, preferably freely available, and be technically of high quality. At present there are no complete standards covering telemedicine and its integration into other medical information systems. There are many different systems available, but choosing the right system for a specific use is not an exact science. It is possible that none of the systems available today is good enough for tomorrow's needs. Standardisation will develop further, and it is expected that there will be some convergence. To take telemedicine to the next level and to enable comparisons as to the merits and benefits of different systems and to maximise the use of data collected in telemedicine systems it is desirable to develop standards for the preparation, transmission and collection of data.

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Publication IV

The EU medical devices legislation in diabetic retinopathy screening

By

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The New EU Medical Devices Legislation in Diabetic Retinopathy Screening

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Background

The number of diabetic patients is large and growing [1]. This increases the demand for retinopathy screening. The screening is usually performed by using digital fundus photography.

As the screening workflow is a digital one, it is covered by some recent changes in the EU Medical Devices Directive (MDD) [2] . Even though the workflow seems straightforward, the implications of the MDD onto it are not necessarily clear.

The rationale behind the MDD is to remove software or hardware-related faults in the diagnostic chain. The scope of the directive is currently very wide, and it leaves a lot of room for interpretation.

This study has been carried out to help clinicians to understand the possible implications of the MDD.

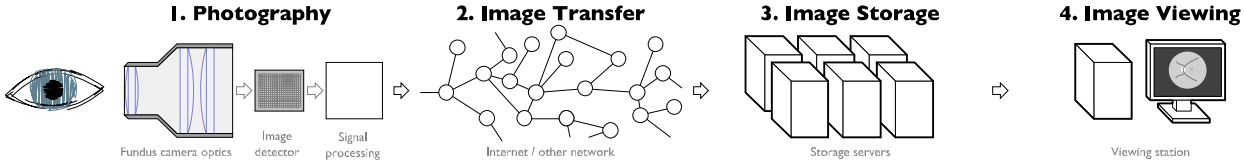
Fundus Imaging Workflow

In our work we have identified the different pieces of software and hardware typically used in the diabetic retinopathy screening. We have analysed the main diagnostic risks and reflected the MDD onto the workflow steps.

Technically, there are four distinct steps per eye in a typical workflow: photography, image transfer, image storage, and viewing. The steps are outlined below, and the main parts of the devices are shown along with some risk analysis. In practice, the image storage and transfer steps may be in different order or even occur multiple times during the workflow.

It should be noted that this is only one view into the workflow and MDD; due to the wide scope of the directive it is impossible to show all potential details which have to be taken into account.

Hardware, software and risks in diabetic retinopathy screening



	1. Photography	2. Image Transfer	3. Image Storage	4. Image Viewing
Hardware	Fundus camera optics, digital camera	Network hardware, storage media (CD/DVD, USB stick, memory card)	Network hardware, ITC infrastructure hardware (servers, etc.)	PC hardware, computer display
Software	Digital camera software	Standard computer software	Server software	Viewing software
Analysis	The optical system is clearly diagnostic equipment, it has an effect on the image quality. The digital camera software is also important, as it performs image processing. The camera software is usually proprietary software with no exact specifications available. The main risk is the camera image processing introducing image errors which may pass visual inspection undetected. Optical system or camera image detector faults are practically always visible in the image.	All data transferred over the network (or storage media) may become corrupted in the transfer. Most data transfer methods ensure that each file is either fully transmitted or not transmitted at all. If this is not the case with the transfer protocols in use, the data may also be transmitted in a corrupted form. Also the metadata (patient data, etc.) of the image may be corrupted or lost.	It is often impossible to identify all the infrastructure associated with image storage, but its overall risks can be estimated. Faults in storage software or hardware compromise the diagnostic quality in the same way as with image transfer; the image or its metadata can be lost or corrupted. If the image storage software performs further image compression (or decompression/compression cycles), the image quality may deteriorate.	The viewing hardware and software have a very significant effect on the reproduction of the fundus images. While the operations performed by the viewing software - such as zooming, contrast and brightness adjustments - seem trivial, they may introduce artifacts into the image. Also, the properties of different computer displays - such as resolution, color reproduction, contrast - and viewing conditions are very significant in this sense.

Discussion

The fundus camera system seems to be a medical device governed by the MDD; it has several parts and functions which have an impact on the reliability of the diagnostic outcome. However, even with the relatively simple system used in diabetic retinopathy screening, it is quite difficult to define which parts of the system carry real diagnostic risks, and which parts of the system belong to the scope of the MDD.

For example, the viewing conditions (lighting, etc.) and computer display used in the viewing the images both have an impact on the image reproduction. Yet, the viewing conditions are most probably not in the scope of the MDD, and even the display settings are unlikely to fall within the MDD.

Probably the most complicated situations arise with the software in a diagnostic system; the medical device classification of a computer program depends on the intended use of the piece of software.

The MDD scope has been extended in 2010 to cover software intended for diagnostic or therapeutic purposes. Despite it being a part of current EU legislation, it is not well-known among the users of these devices.

It is interesting to compare the modern digital diagnostic systems with earlier non-computerized systems. The diagnostic retinopathy workflow used to be carried out with paper photographs and manual archives. The actual risk factors in this old workflow are essentially the same (loss of images, bad image quality, confusion in patient data), but the more likely human errors in the manual workflow are outside of the MDD.

It seems that the aim and purpose of the MDD is unarguably good, but its practical implications and interpretation require more consideration from all parties involved from the device manufacturers to end users.

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Publication V

Decision making process for clinical IT investments in a public health care organization – contingency approach to support the investment decision process

By

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Decision making process for clinical it investments in a public health care organization – contingency approach to support the investment decision process

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Abstract

Purpose Health care organizations are lacking a clear decision-making framework in IT investment decisions. This study aims at finding a practical tool able to take the different financial and non-financial factors into account. The usefulness of one possible tool, the Contingency Theory, is evaluated.

The Contingency Theory seeks to understand which external factors in particular have an impact on the organization's operations or which internal factors must be taken into account to make the optimal investment. In the public health care context the internal variables such as organization's culture and condition of existing technology, and external variables such as legislation and politics play an important role.

Methods The Contingency Theory is applied to a complex real-world investment case a posteriori, and the variables thus obtained are compared with the actual acquisition process which took place. The relevant information has been gathered from the accounting systems, and by interviews.

Results The Contingency Theory finds a relevant set of variables to consider in the decision-making process, and the set of variables mostly coincides with the actual parameters considered in the decision-making process. The actual acquisition process placed more weight on cost factors than the Contingency Theory approach would have done.

Conclusions The application of contingency theory suggests that in this case the expected value of costs was overemphasized. It is likely that a contingency-based approach would have given a more balanced view of the different parameters. Further research is required to establish its usefulness in different types of public health care acquisitions.

Keywords: costs and cost analysis, economics, health information management, case management, signal processing, computer-assisted software

Introduction

The complex environment in the health care sector makes the investment decision-making process when investing in Information and Communication Technology (ICT) often more complicated and thus slows down the investments [1,2,3,4,5]. There are several relatively straight-forward cost factors—such as costs associated with hardware and software, availability of broadband and mobile networks, and ongoing maintenance costs—evident in the ICT investment decision-making process [6] but there are other financial factors whose value is difficult to evaluate during the decision-making, e.g., ongoing development of technology, present level of standardization, and interconnectivity between IT systems [7-9]. While even these factors can theoretically be assigned a financial value, there are also non-financial factors associated with the clinical IT systems. These could be related to the health care outcome (e.g. patient comfort, equality of care) or organizational factors, such as willingness to adopt new technology. These non-financial values may carry a strong emphasis in the public health care sector where the aim is often to produce as good health care as possible within the given budget instead of producing profit.

The growth in ICT spending and a broadening menu of technological investment choices have lead health care organizations to critically evaluate potential investments for the value they deliver [5,10,11]. Allocating resources among competing investment projects is one of the most critical elements of the whole process [12,13]; while capital budgeting is used to vet the competing investment projects [12,14,15]. Empirical evidence suggests that financial analyses beyond cost analyses are still rarely used in clinical IT investment decisions in health care organisations [16,17]. Health care organizations are lacking a clear decision-making framework which would aid in structuring IT investment decisions [18]. The objective of this study is to apply the contingency theory to see if it can be used in a clinical IT investment decision-making and to develop more information related to management practices. And also if the variables found could be expressed in form of a tool which is both able to take the different financial and non-financial factors into account and simple enough to be applicable in practice.

The case examined in this study is a large-scale ECG measurement, analysis, and storage system acquired by a public health care organization (see Case description). The investment decision was primarily driven by project finance and economics, but those core variables had to fit within a specific regulatory and political context in order to be successful owing to the public sector-nature of the investment.

The investment also illustrates the fact that while it seems to be an intodiagnostic equipment investment, the core of the investment is information. The instruments produce information which has to be stored, communicated and accessed. Thus such a system can and should be viewed as an IT system.

This study belongs to a series of studies which aim at charting the useful application fields of the contingency theory. [19-31].

Contingency theory and clinical IT investment decision-making process

According to contingency theory the optimal way of leading a company is contingent upon the internal and external situation at hand [32-36). The underlying premise in contingency theory is that organizational performance is the result of a match or fit among salient factors [37,38).

Central to the contingency approach is the notion of contingent fit among relationships between strategic priorities, organizational configurations, and management accounting systems. This approach asserts that neither the type of strategy, nor the organizational configuration will directly affect performance. Rather, contingency theory suggests that the most important determinant of performance is the contingent fit between the chosen strategy and its contextual variables [39].

Contingency theory explains the design of management accounting systems, in which the organizational context

and structure must be in line in order for an organization to perform well [24]. Using the contingency approach researchers have attempted to explain the effectiveness of management accounting systems by examining designs that suit the nature of the environment, size, structure, technology, strategy, national culture and international competition [36,40-43). There are many variables that might have a role designing a management accounting system to support an investment decision-making process. Internal variables cover the organization's strategy, culture, technology, structure and size, and external variables cover the organization's operating environment.

According to contingency theory, the effectiveness of decision- depends upon a number of aspects within a specific situation including the amount of relevant information and decision quality and acceptance [44]. The contingency approach is not commonly applied into the study of decision-making, but it is chosen to be evaluated in this study due to its main proposition that structure and process of an organization must fit its context in order to be effective [37]. Contingency approach analyzes the organization's internal and external factors that are expected to affect the investment decision-making.

While the emphasis in investment theories is in dealing with quantitative appraisals of project focus and costs, there is no self-evident methodology for contextual analysis of IT systems beyond financial considerations. Taking the broader context into account would potentially aid health care organizations evaluate the suitability of their IT investments [45] in terms of indirect costs and benefits [46].

Based on such a theoretical understanding of contingency theory and authors' previous empirical studies on cost-analysis in telemedicine and clinical IT investment studies in public health care organizations [47-55) this study adopts the following hypothesis:

The investment decision-making process for a clinical IT system in a public health care organization is positively correlated to the concept of contingency fit which is comprised of three independent variables:

- Strategic priorities :external variables including health care legislation, politics,
- Organizational configuration: internal variables including organizational culture, the role of public organization, the state of existing technology at the time of the final investment decision,
- Internal management accounting systems: non-profit organization, cost-benefit analysis

Material and methods

Applying the theory to a real-world investment case which has already been carried out provides an opportunity to use more than one method of data collection (questionnaires, interviews, informal conversations, meetings, material provided by the organization such as business plans, strategies, survey data and other observations) thus enabling perceptual triangulation, which ensures that a more accurate interpretation of the situation is made [56-59] by answering questions "how" and "why" [60] in addition to creating theoretical constructs and propositions from empirical evidence [61].

Written documents

The documents used in case evaluation included

- organization's strategy papers,
- IT strategy,
- materials related to the vendor selection process,
- investment analysis and selection criteria,
- results from the selection process,
- standard agreement templates for acquiring the system, maintenance and support service,
- material presented for the board of directors related to the purchase, and
- publicly available minutes of the Board of Directors of Hospital District of Helsinki and Uusimaa (HUS)

The material including information from the organization's accounting system follows the case from 2005 until the final investment decision was made by the board of directors in May 2008.

Interviews

To gain a comprehensive understanding of the case the administrative chief physician was interviewed in six semistructured interviews. Before each interview and during the analysis of the interview data, the researcher studied organizational documents mentioned above. Interviews were documented and several follow up questions were submitted by e-mail for clarification and additional information was provided also by other experts in the project.

The interview questions were related to the purpose of the investment and the overall procurement process in order to best reflect HUS' overall decision-making strategy, the contributing environmental contingency factors and criteria selected for the vendor selection process. In addition, during the interviews supplementary data was collected and analysed regarding the overall strategy of the organisation. This way of gaining more information was very important in order to understand the decision-making and how different decisions were linked each other.

Accounting data

Also, the financial data from the accounting system related to the volumes, costs and prices was analysed in detail. The degree of rigor applied in this study was meant not only to improve the reliability of the analysis based on interviews but also to enhance the understanding of specific details related to the investment calculations. While this analysis provided detailed information on the case, the main aim of this study is to evaluate if the contingency theory can be successfully applied in analysing this type of investment decision.

Results

The case was analysed from two points of view. The first viewpoint is the contingency approach ("what should have been taken into account"), and the second viewpoint is an analysis on the actual acquisition process.

Contingency approach and contingency variables

According to the contingency theory the effectiveness of the decision-making process can be explained by examining designs that suit the culture of the organization, nature of the environment and technology. This requires identifying contingency variables. As stated in section 2, the hypothesis emphasizes that the contingency variables can be divided into three categories: externalities, organizational culture, and technology. Figure 1 depicts the variables used in this case. The following section describes the contingency variables which – according to the contingency theory and our hypothesis – should have been taken into account in the acquisition process.

Organization's culture

HUSLAB is the leading provider of clinical laboratory services in Finland. HUSLAB's main area of operation is the Hospital District of Helsinki and Uusimaa (HUS) – a joint authority formed by 24 municipalities. HUSLAB has over 70 sampling points around the Helsinki and Uusimaa area, where nearly 20 million tests are carried out annually. HUSLAB is a public utility able to set its own prices but selling 90 % of its services to the HUS municipalities.

HUSLAB started operations in 2004. One of the objectives for separating laboratory activities from the hospital district was that the costs can be better identified. At the time of the investment decision the entity was also able to make profits and the positive cash flows were used for financing investments. Today HUSLAB makes "zero" results and investments, i.e. financing, are separately decided at the Hospital District level.

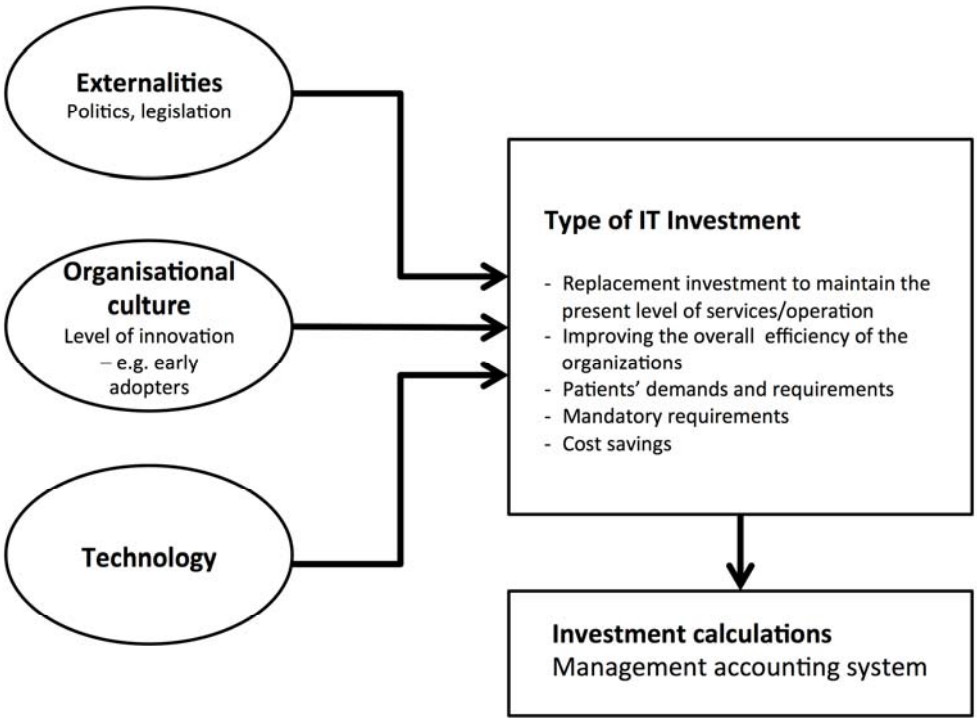

Figure 1. The contingency variables which should be driving the investment decision-making process when investing in clinical IT systems.

Externalities

During the preparation of the IT system investment a law related to the electronic data processing in health care services passed the Finnish Parliament. The law required health care entities to ensure the ability to store patient records electronically in the national archives not later than April 1st 2011, which increased the strategic importance of the investment in question within a wider institutional context.

Technology

The goal of the investment was to provide paperless ECG operations with the ability to view ECG records at remote workstations. The intention was also to create a system with similar equipment and procedures that could be used in the Hospital District and by the health care professionals in HUS's member municipalities.

The driving forces behind the ECG system investment were the need to harmonize the process within the hospital district and to create cost savings. There was also a demand to provide interfaces to integrate the laboratory system in the existing ordering and laboratory result delivery system. Standardization was an important parameter during the decision-making process. Before the purchase of the new digital ECG recording, analysis, and storage system there was a long discussion between HUSLAB and the Ministry of Social Affairs and Health about the relevant standards. At that time there were no uniform standards for digital ECG activities neither in Finland nor in the EU.

Acquisition process

The actual acquisition was carried out by using a few financial calculations and according to the existing legislation. The legislation had a significant influence on the

acquisition process; according to the Public Procurement Act § 29, the financial value of the purchase should be the most relevant factor in decision-making. Financial performance was analysed by estimating three vendors' tenders overall financial benefits. Table 1 presents the criteria and the importance of them in the selection process.

The most important criterion was the overall price with a total weight of 40% and the second most important criterion was the quality of support and maintenance services including the annual fees for the services. Previously, hospitals paid all licences and equipment in cash and booked investments on their balance sheet. In contrast, the new system was acquired as a service and the selected criteria (overall price, maintenance costs and support services) covered the total annual cost for the system.

After testing each system offered by the qualifying vendors the evaluation group evaluated the functional benefits and usability of each system. The analysis on usability was mostly based on subjective assessments. The interoperability of the systems was evaluated and analysed by the answers given by each system vendor.

Cash flow, scorecard or pay-back type of investment calculations and analyses were not presented in the case material. Management account reporting which was established in the new entity did not follow the financial performance of the investment itself, as it was created more to support the Enterprise's (HUSLAB) overall results. HUSLAB introduced a balanced scorecard model for cost accounting and the first pilots were already running in 2005, but it was not applied to this project.

In addition to the financial criteria, there was one important technological criterion; while there were no standards in place, only some EU level discussion, only the systems that had been used in other organizations were selected for the evaluation.

Table 1. The selection criteria for the competing systems.

Criterion	Weight
Price of the licence and modification work	**40 %**
Quality including technical merits of the systems, as well as maintenance and support services	**30 %**
Functional benefits including the user-friendliness of the system	**10 %**
Interoperability, the possibility to integrate the system into the present IT environment	**20 %**

Table 2. The number of ECG test and ECG devices between 2008 and 2012.

Year	Number of tests	Number of devices
2008 (prior to digital ECG)	240 000*	470**
2009	195 905	229
2010	390 737	297
2011	422 353	314
2012	403 709	334

*Estimate, of which some 130 000 were carried out by HUSLAB
**The number of devices in registry, of which some 200 were in active use.

Outcome of the system acquisition

The new system was fully implemented in 2011 and Table 2 illustrates the number of ECG tests and number of devices in use during the years 2008-2012. The number of devices in active use and tests performed increased during 2008 – 2011 until the system was fully implemented in. The decrease in the number of tests after 2011 is explained by a decline in unnecessary re-examinations for the same patient due to the availability of patients' data in a digital format.

Even though HUSLAB operates as a non-profit entity, the organization has to keep its costs down to manage end consumer prices. HUSLAB's ability to provide ECG services at a relatively low cost supports the view that the IT investment was financially beneficial for the organization. Table 3 illustrates the development of the prices during 2008 – 2013. The reference price (base price is the price during the normal working hours) of conventional paper ECG in 2007 was 10.00 euro and the on-call price in 2007 was 14.50 euro.

The ECG prices for HUSLAB's clients have increased 3.7 % per annum (table 3) while at the same the overall costs in health care sector have been increasing 5.4 % [62]. The increase in the prices is mostly explained by the increase in real prices (inflation, labor costs). The increasing prices in 2012 and 2013 are explained by the fact that the total cost of the system is allocated into test prices, and as the number of tests has fallen, the cost for a single test has risen. However, the data of 2011 and 2012 shows that the total cost has decreased, i.e. the same result can be obtained with less money.

Evaluation of the contingency theory application

When evaluating the applicability of the contingency theory approach, the question is whether applying it to this specific case would have given optimal outcome. Would there have been some variables which could have been better accounted for, or would it have missed something. This question has also a very strong subjective side in whether the application of the contingency theory would have felt natural and been simple enough to be useful in the decision-making process.

The outcome of the IT system investment was according to HUSLAB's initial expectations: processes improved with harmonisation of digital ECG recording, analysis, and storage while the cost level has been kept at the same or even lower level. Clearly, the test case was a successful one, and the actual course of the process can even be thought as a benchmark.

The investment decision-making process showed that the hypothesized contingency variable groups yielded relevant variables while analysing the investment decision:

Table 3. Price trend (in euros) of the ECG examinations between 2008 and 2013.

Year	Base Price	On-Call Price
2008	10.00	14.50
2009	11.00	13.50
2010	11.50	15.00
2011	11.90	15.00
2012	12.25	15.45
2013	12.60	15.90

Externalities

There was observable legislative pressure which enabled the organization to renew its present system with a new digital ECG system. According to the interviews, the acquisition of the new system also resulted to a redesign of the HUSLAB's processes.

Organizational culture

Even though in the HUSLAB case the external, environmental factors–both political and legislative–drove the need for the investment, the organization itself had a major impact on the decision as well. In the case the management team comprised of professionals with diverse backgrounds who looked for new and innovative ways to implement services. In addition, an organization's culture has a palpable influence over the degree of innovation for providing health care services. While in the case organization, the final investment decision will be made by politicians, it is very important that the organization brings to decision-makers well-founded and prepared presentations, such as this case was.

Technology

Technology itself played a key role in the investment decision – the new open application interface was better integrated into the present IT environment which subsequently enabled further process improvements. When discussing the clinical IT system, standards play an important role. Since there were no uniform standards for digital ECG activities, in the HUSLABS case the system was selected because it was already in use in a few other hospitals.

It seems that the factors identified by the contingency theory were relevant factors. They were to some extent taken into account in the case without the contingency context, but using contingency theory and examining the fit between the most important variables would possibly have helped HUSLAB to have more structural decision-making process.

The most notable difference is in handling the cost as a factor. The actual acquisition process set a very strong emphasis on the cost, but at closer inspection the most important factor variable was technology, i.e. standards and integration, as only systems having open interfaces and prior installations were accepted.

There were also legislative changes which impacted the decision-making process; the change in legislation helped the management to get the needed resources from the decision-makers (politicians). This is an example of another contingency factor which was in reality taken into account, but does not show in the process.

Discussion

During the study it was found that the original contingency model goes quite far to demonstrate how management accounting systems, external strategic priorities and organizational configurations contribute to explaining clinical IT decisions-making in the case studied.

Intuition vs. Contingency theory

The lack of a structured method to take the complex environment into account seems to lead to a situation where decisions are often based on intuition and recommendation by trusted parties. While this more intuitive line of work may produce good results, it has its obvious risks. This problem becomes more acute, as today's IT systems are becoming complex and intertwined, and an increasing amount of specialist knowledge is needed to understand the essential details.

One of the main challenges is the integration between different systems. There are numerous different systems from different vendors in today's health care environment, and if these systems do not interact fluently, it will introduce unnecessary friction into operational processes.

The contingency theory is about strategic fit. A practical example of this is that some organizations–such as

HUSLAB in our case–want to use new technology, whereas some other organizations may want to adopt new technology much later in order to benefit from acquiring mature and cost-effective technology. Neither of these strategies is worse than another *per se*, but the optimal investment type and investment schedule is probably quite different with this kind of strategic differences.

The Contingency Theory seeks to understand which external factors in particular have an impact on the organization's operations and, correspondingly, which internal factors must be taken into account so that the organization is making the optimal investment decision in terms of process performance. The application of contingency theory to this case study suggests that in the decision-making process, the internal variables such as organization's culture and condition of existing technology are supported by the externalities such as legislation and politics, which are important variables in a public health care organization's decision-making.

Even though the case we used to test the contingency theory in this context was a highly successful one, the application of contingency theory shows that in this case the expected value of costs was over-emphasized. Had there not been any external pressure, no investment decision would have taken place. In this case the contingency theory would have given a more balanced view of the different parameters. The investment decision was made due to the strong views and intuition of the leaders instead of a structured process.

Using the contingency approach in financial calculations

We are optimistic about the opportunities opened by applying the contingency theory into complex health care IT investments. However, we talk about investment projects, and in addition to qualitatively identifying the contingency factor we will need to be able to integrate them into the financial calculations. In order to do that we suggest a modified version of the commonly used Net Present Value (NPV) formula [63]:

$$\mathrm{NPV} = -I\frac{1-\delta}{1+\alpha+\beta} + \sum_{t=0}^{N}\frac{R_t}{(1+i)^t} \quad (1)$$

where
I is the actual cost of the required investment,
α the possibility for the system to be integrated into the present and future environments ($\alpha \geq 0$),
β is a factor which describes the level of IT technology ($\beta \geq 0$),
δ is the strategic fit of the required investment ($0<\delta\leq 1$)
N number of years to take into account,
R_t net cash flow on year t (excluding initial investment), and
i discount rate

This is essentially the same as the standard NPV value apart from the coefficient of the investment. If the strategic fit would be excellent, the effect of the investment can be regarded to be zero. Also, if the level of IT technology (in the organization) or the future integration prospects of the system are very good, the cost of the investment diminishes from the organization's point of view.

This modification of the NPV method should enable one to factor in the total effect of the contingency variables. Admittedly, determining the values of α, β, and δ have a great variability, but the formula still provides a way towards quantifying the complex and contingency factors which tend to be qualitative in nature.

Next steps

Naturally, as this study is based on testing a theory on a single case, its results may not be valid when generalized to other cases. This study does not give a complete recipe on how and when to apply the Contingency theory into clinical IT investments, but it may provide a starting point for practical application and further research. Our earlier personal experience with clinical IT investments suggests that there are many common factors which are quite independent from the actual system which is being purchased.

As such, contingency theory should be further tested on cases in which the independent variables are not aligned symmetrically, thus providing more insight into how the variables interact with one another under less than optimal conditions and creating the opportunity to scrutinize the role of individual agency more closely.

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Case: HUSLAB's digital ECG recording system investment

HUSLAB is a large publicly owned provider of laboratory services in Helsinki, Finland. HUSLAB purchased in 2008 an information system for digital ECG recording, analysis, and storage. The system was intended to replace all existing earlier generation systems, and to give, e.g., savings and paperless operation. At the time of the purchase time HUSLAB carried out some 240 000 ECG examinations a year and over 200 ECG recording devices were in use.

The purchase was performed in accordance with the Public Procurement Act § 29 (competitive dialogue), because it was not possible to determine in advance the legal and economic conditions, or exact technical specifications of the system. A short list of referenced vendors was created so that only vendors who were able to provide interfaces with existing systems were chosen. During negotiations, vendors were able to present the Hospital District with systems meeting the requirements set by the project management. One of these systems was chosen to be the new ECG system.

Appendix 1

CASE HUSLAB: the structure of the interviews

The first meeting: the questions prepared and the topic to be discussed

Please explain HUSLAB's history as an organization.
What was the strategy of HUSLAB and what is the relation to the overall strategy of HUS?
What was the IT investment and why was the investment needed? What were the driving factors /the needs behind the investment decision?
How would the investment support HUSLAB's strategy, i.e. IT strategy?
Please describe the organization's structure and resources. What was the project organization like?

At the meeting, HUSLAB's strategy, material related to balance scorecard development as well as the picture related to the IT systems architecture were presented. Also material related to the Board meetings (also available online) and decision-making phases of Board meetings were provided. The templates for purchase as well as maintenance agreements were also provided.

After the first meeting the available financial data was sent by e-mail. For the preparation of the second meeting, the following financial material was provided:

- the number of tests and the costs related to the operation from the accounting system;
- the running maintenance and license costs were also provided.

The second meeting: the questions prepared and the topic to be discussed

Let's have a further discussion about the financial data provided in relation to the IT investment.
What were the bases for making the investment analysis and decision? And the criteria used?
What was the overall goal for the investment, i.e. operational and financial goals?
What are the financial outcomes from the investment? (Discussion about the data sent by e-mail and clarifications needed.)

After the second meeting, more financial data was provided.

The third meeting: the questions prepared and the topic to be discussed

What was the overall IT infrastructure, i.e. in which kind of IT environment was the system considered to be implemented?
Please describe the standard and the discussion with the Ministry/EU.
Please describe the investment evaluation process, i.e. the parties involved in the decision-making as well as the types of material used.
What type of a purchase was this? And why was structured in that way?

The fourth meeting: the questions prepared and the topic to be discussed

Who was the decision made by and how was the project started?
Please provide information regarding the project itself and the different phases in it.
What kinds of discussion were there between different stakeholders, and what were the identified stakeholders?
What kind of accounting data was provided for the decision-making?
How is the organization following the development of the results?
Are there already financial, such as cost, benefits obtained from the system?

The fifth meeting: the question prepared and the topic to be discussed

HUSLAB organization itself
How was the project organized and what kinds of resources were there? (This was not discussed at the first meeting.)
The training and the implementation plan
Is there any information regarding the operational benefits already available from the system? Any feedback from users, patients? Has it improved the quality of care?

The last (sixth) meeting involved going through the Case HUSLAB and the analyses made, going through the findings and clarifying the remaining open questions.

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